MECHANICAL ENGINEERING

INCLUDING THE ENGINEERING INDEX

U. S. NAVY CRANE SHIP NO. 1.

JUNE 1923

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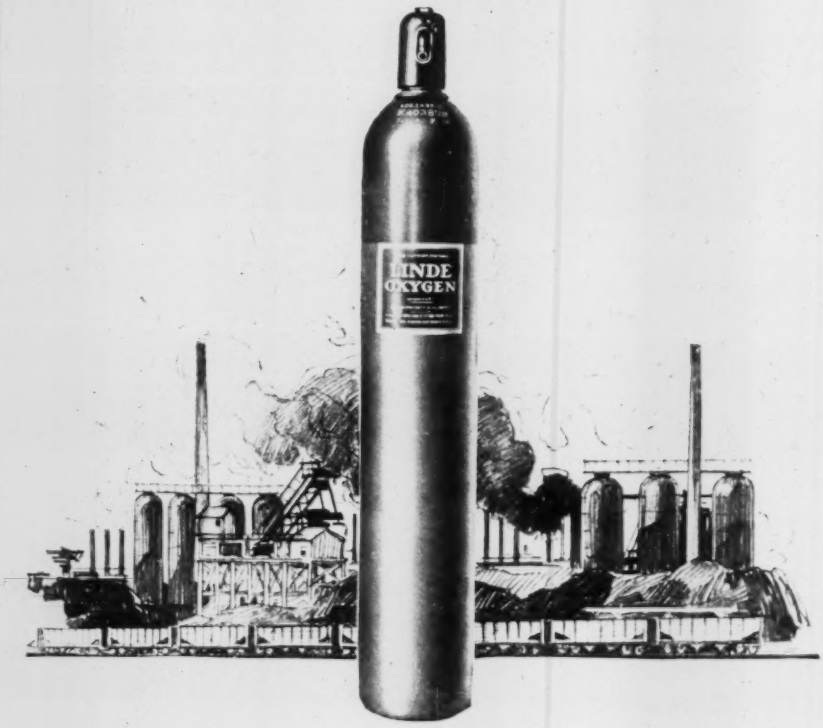

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Contributors and Contributions

U. S. Navy Crane Ship No. 1

The vital part that high-grade engineering plays in the defense of the country is reemphasized by the article in this issue describing the largest floating crane in the world—and the only sea-going one—into which the old battleship *Kearsarge* has recently been converted. The difficult nature of the engineering problems involved in rebuilding the hull and in constructing the crane will be readily apparent, and their solution reflects great credit upon American engineers, in particular those of the U. S. Navy and of the Wellman-Seaver-Morgan Company who were charged with the responsibility for the achievement.

Orifice Coefficients

Jacob M. Spitzglass, vice-president and consulting engineer of the Republic Flow Meters Company, Chicago, Ill., presents a paper discussing the results of extended experimental work conducted at the research laboratory of his company on the use of orifice plates for measuring the flow of fluids in pipes.

Mr. Spitzglass was born in Russia in 1869. After unsuccessful attempts to obtain a technical education there and in Western Europe he came to America and in 1909 was graduated from the Armour Institute of Technology with the degree of B.S. in mechanical engineering. Four years later he received his M. E.

His first position after graduation was with the Northwestern Gas Light and Coke Company. Then for a year he tested steam engines for the Armour Glue Works and experimented in measuring the flow of steam to the various lines of the concern. He later was engaged to do experimental work for the People's Gas Light and Coke Company and won recognition for his work relating to the flow of fluids through pipes. He improved and developed the Gebhardt steam meter. This meter is now being manufactured by the Republic Flow Meters Company. Mr. Spitzglass has received the Longstreth Medal for his work in developing and correcting the defects of the steam meter.

Recent Developments in Balancing Machines

With the increased speed and capacity of motors the necessity for satisfactory balancing equipment has been keenly felt, especially for the balancing of small high-speed motors for domestic use. A machine which makes it possible to manufacture quietly running motors is described by Carl R. Söderberg in this issue.

Mr. Söderberg is a native of Sweden, where he was born in February, 1895. He was graduated from the Technical Preparatory School at Härnösand in 1914, served two years as an apprentice in the shipbuilding industry, and then entered Chalmer's Institute of Technology, Gothenburg, from which he was graduated in 1919. With a scholarship from the American-Scandinavian Foundation for study of the shipbuilding industry in America, he came to this country and pursued post-graduate work at the Massachusetts Institute of Technology and the University of Michigan until June, 1920. Since then he has been employed successively by the New York Shipbuilding Corporation at Camden, and the Westinghouse Electric and Manufacturing Company at East Pittsburgh, where he has specialized on vibration problems.

Steel-Car Construction

The first box car having its entire frame built of steel was originated by the Canadian Pacific Railway nearly fifteen years ago. In this issue H. R. Naylor, assistant works manager of the Angus Shops of the Canadian Pacific, at Montreal, Canada, describes the shop specially erected to fabricate the steelwork for these cars, giving particulars regarding its layout, crane facilities, machine equipment, etc. He presents the various machining operations and the jig method of car assembly now employed and the method used in the final erection and finishing of the cars.

Mr. Naylor was born in England in 1885 and served his apprenticeship in railway engineering in that country. He entered the service of the Canadian Pacific Railway Company in 1907 as patternmaker and has served that company in various capacities since that time, assuming his present position about three years ago.

Industrial Safety Codes

The brief paper on the development of industrial safety codes appearing in this issue was presented by M. G. Lloyd, chief of the Safety Section of the U. S. Bureau of Standards, and vice-president of the American Society of Safety Engineers, at a joint session of that society and the A.S.M.E. Safety Codes Committee at the A.S.M.E. Annual Meeting in December, 1922.

Mr. Lloyd is a graduate of the University of Pennsylvania, which has conferred upon him the degrees of Bachelor of Science, Doctor of Philosophy, and Electrical Engineer. After serving as instructor of physics at this university he became connected with the Bureau of Standards and was engaged for several years in electric and magnetic testing and research. From 1910 to 1917 he was technical editor of the *Electrical Review and Western Electrician*. He returned to the Bureau in 1917.

Code for Care of Power Boilers

The Proposed Code for the Care of Power Boilers, formulated by a Sub-Committee of the Boiler Code Committee and containing rules for the care of steam boilers and other pressure vessels in service, is now presented for public discussion. A hearing on this report is on the program of the A.S.M.E. Spring Meeting at Montreal. When revisions are completed this report will form a part of the A.S.M.E. Code.

A.S.M.E. Spring Meeting

The Montreal Meeting of The American Society of Mechanical Engineers is in progress as this issue of MECHANICAL ENGINEERING is being mailed. An account of the technical sessions will appear in the July issue.

The A.S.M.E. News for June 7 will tell of the excursions and of the social events.

MECHANICAL ENGINEERING

Volume 45 June, 1923 No. 6

U. S. Navy Crane Ship No. 1: An Achievement

Details of the Conversion of the Battleship "Kearsarge" into a Titanic Seagoing Crane for Handling Loads of 250 Tons—The Engineering Problems Encountered in Dealing with Stresses of Unprecedented Magnitude and How They Were Solved

WHEN in an engineering structure the size exceeds certain well-tested limits, the difficulties of design and construction multiply at a very rapid rate. There have been many instances of this character. Steel bridges have been built for many years, but when it came to an enormous structure like the Quebec Bridge it was found that our knowledge of stresses of the magnitude involved was insufficient. The same type of difficulty was encountered and overcome in converting the battleship *Kearsarge* into a seagoing crane ship capable of handling and transporting two modern three-gun turrets complete with their guns.

"U. S. Navy Crane Ship No. 1" as it is known officially but called the "*Kearsarge* Crane," is the only large seagoing crane ever constructed and the largest floating crane in existence. Big floating cranes have been built in the past, but only for harbor work and not for navigation in rough water or in heavy seas. The *Kearsarge* bears a 250-ton revolving crane of the luffing-jib type so designed that the jib may be lowered into a cradle and secured firmly for sea service. Built to handle loads of 250 tons under normal conditions, she has actually lifted 312 tons. Such loads on a floating structure impose stresses of an unprecedented character, both on the crane and the foundation, which means that all parts have to be designed with unusual care, generous factors of safety, and with particular regard to the selection of materials in order that there shall be no weakening of any part due to overstressing. To meet these conditions interesting expedients and methods of design were resorted to, both by the Navy Department, in whose hands was the reconditioning of the hull, and by the Wellman-Seaver-Morgan Co., of Cleveland, Ohio, the builders of the crane itself. Among these may be mentioned a new method of combined welding and riveting ship plates, the novel track arrangement for the crane, the rotating mechanism—provided with wheels of a new type, the methods of cradling the crane at sea, etc.

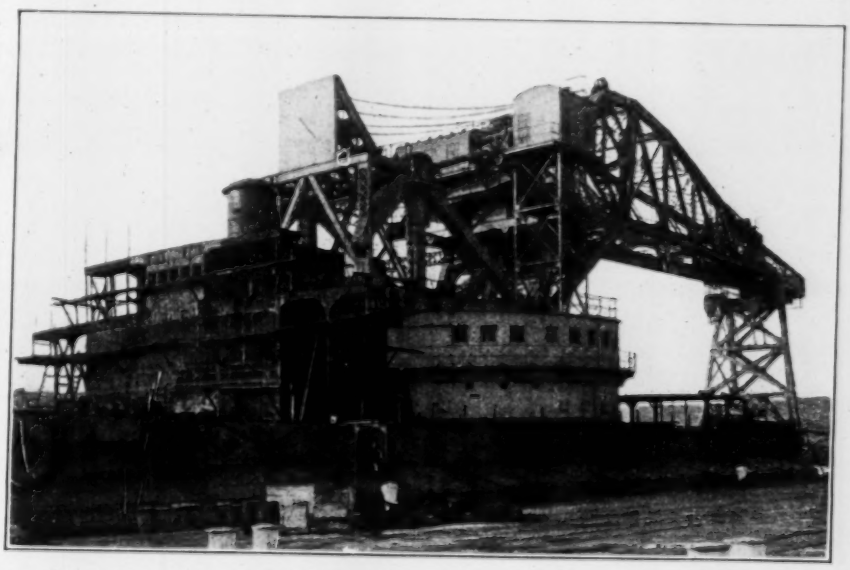

FIG. 1 WHEN READY FOR SEA, THE JIB RESTS IN A CRADLE AT THE STERN OF THE CRANE SHIP

SPECIAL USEFULNESS OF THE LARGE SEAGOING CRANE

Cranes of this type are expected to prove useful in many ways. For fitting-out purposes, handling guns, turrets, boilers, etc., they are beyond comparison with any other type as they can be easily moved to any point where their service is required. This is a very decided advantage as it permits the use of a crane not only at different places in the same base but also extends the scope of operations to yards which would otherwise be unable to command such facilities. The utility of a seagoing crane, however, is not limited to work around navy yards and piers. Its value in salvage operations cannot be overestimated. With the extreme facility of movement possessed by the *Kearsarge* crane, it is quite possible that a sunken submarine might be salvaged if the work were undertaken before the conditions became too unfavorable. In fact, a sunken tug was salvaged during the war by a 150-ton pontoon crane.

The name "Kearsarge"—that of a mountain in Merrimac County, New Hampshire—is one with a long and honorable record in the annals of the United States Navy. The first vessel to bear it was a gunboat hastily built in the early days of the Civil War. Immediately upon completion it was dispatched to European waters to protect United States shipping from the depredations of Confederate privateers. It achieved fame by sinking the *Alabama*, one of the South's speediest and most successful ships. A quaint insight into the knightly attitude of the two American navies is given in the report of Capt. John A. Winslow, of the *Kearsarge*, dated June 19, 1864, from Cherbourg, France, to Secretary of the Navy Gideon Welles in reference to the battle with the *Alabama*. "I have the honor to inform the Department," wrote Captain Winslow, "that the day subsequent to the arrival of the *Kearsarge* off this port I received a note from Captain Semmes [of the *Alabama*] begging that the *Kearsarge* would not depart, as he intended to fight her and would delay her but a day or two." There was no such exchange of notes with the enemy in the recent war. The old *Kearsarge* was wrecked on February 2, 1894, on Roncador Reef in Central American waters, and the construction of a new one was authorized by act of Congress of March 2, 1895. This vessel was built at the Newport News Shipbuilding and Drydock Co. yards, Newport News, Va., and was launched on March 24, 1898.

Old or new, the *Kearsarge* embodied novel features. The original vessel, together with her sister ship the *Kentucky*, was selected for an experiment in the installation of superposed turrets, an 8-in. turret being rigged on top of a 13-in. The later *Kearsarge* and the *Kentucky* (now to be scrapped as a result of the Washington Conference) were the first to be completely equipped with electric auxiliaries such as turret-operating machinery, deck winches, ventilating fans, etc.

BEGINNING THE WORK OF CONVERSION

After the World War the need of a mobile crane for the use of

the Navy became apparent, and the conversion of the *Kearsarge* into a crane ship was decided upon largely because the hull of the vessel was in an excellent state of preservation and suitable for the purpose in view.

At the beginning of the conversion the guns, turrets, much of the armor, the upper works of the vessel, and a number of the boilers were removed. Little was done to the hull, but it was found necessary to widen the beam by the construction of large bulges on the outside of the hull for the purpose of increasing its transverse stability. These bulges are divided into a number of watertight compartments.

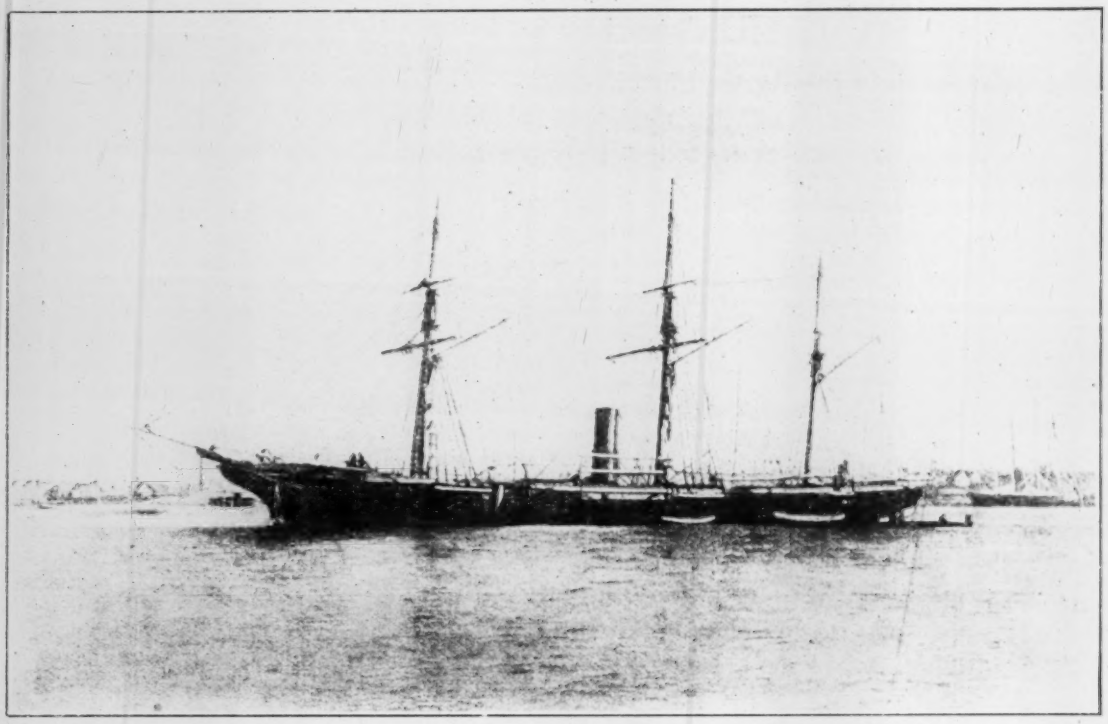

Plate from "Romance of the American Navy." Courtesy G. P. Putnam's Sons

Fig. 2 The First U. S. S. *Kearsarge* Became Famous Through Sinking the *Alabama* Off the Coast of France in 1864

Reinforcing the Hull

In order to carry the immense load and stresses imposed by the presence of the crane and possible loads of the upper decks, the whole ship structure had to be materially reinforced. Just to show the magnitude of these loads, it may be stated that a preliminary calculation showed that the presence of the crane would impose a tangential load of the order of 460,000 lb. acting with a lever arm of 42 ft. 8 in. from the top of the roller path of the crane. So great were these loads that for a while it appeared to be doubtful whether the hull of the ship would be strong enough to withstand their terrible tearing action. The entire structure was accordingly reinforced by an ingenious and liberal use of columns, gusset plates, etc.

In this work some interesting expedients were adopted. Thus, the entire main deck consisting of triple plates was, in addition to the usual riveting, electrically butt-welded in such a manner that the top plate is now practically a single piece from end to end.

In the matter of carrying the main deck loads by the vertical partitions, it was found difficult to select a design of angle which would have sufficient metal left after the necessary rivets had been driven in. It was one of the cases familiar in bridge construction of either enough rivets and not enough metal left in the plate, or enough plate and not enough rivets. The problem was solved after preliminary tests in the ingenious way shown in Fig. 3. Here the vertical wall does not quite reach to the horizontal plate, and the angle in addition to being riveted is welded to the vertical plate all along its lower edge. The result is that much of the shear stress is taken off the rivets and transferred to the welded edge, which under these conditions is capable of carrying safely quite a considerable load.

This is but one instance of the care in design exercised by the engineers of the Navy Department in the reconstruction of the hull. Another is that all doors in the inner walls of the hull are made oval shaped and reinforced by heavy plate frames.

The duty of the Navy Department in reconstructing the hull for the reception of the crane ended with the preparation of the main deck carrying frame for the crane. This latter represented substantially a ring roughly 60 ft. in diameter the upper surface of which had to be level within very close tolerances. This was made possible by increasing the rigidity of the hull structure by the means referred to above. A rather interesting water level which was rigged up permitted the testing of any number of points on the circular track simultaneously.

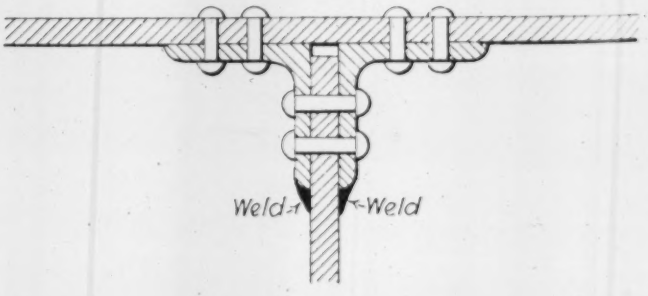

Fig. 3 Method Used in Attaching Vertical Wall to Deck Plate

Nature of the Engineering Problems Involved

The engineering problems encountered by the Navy were, however, only a small part of those involved in the construction of the crane proper, this latter having been carried out under contract by the Wellman-Seaver-Morgan Company, of Cleveland, Ohio. Stationary cranes had been built in sizes much larger than the *Kearsarge* unit and floating cranes of a type much smaller, but never before had it been attempted to complete a floating crane of this size. Such construction involved difficulties of a nature never before encountered. In the first place, the designer had to deal with stresses of an unprecedented magnitude and little-known character.

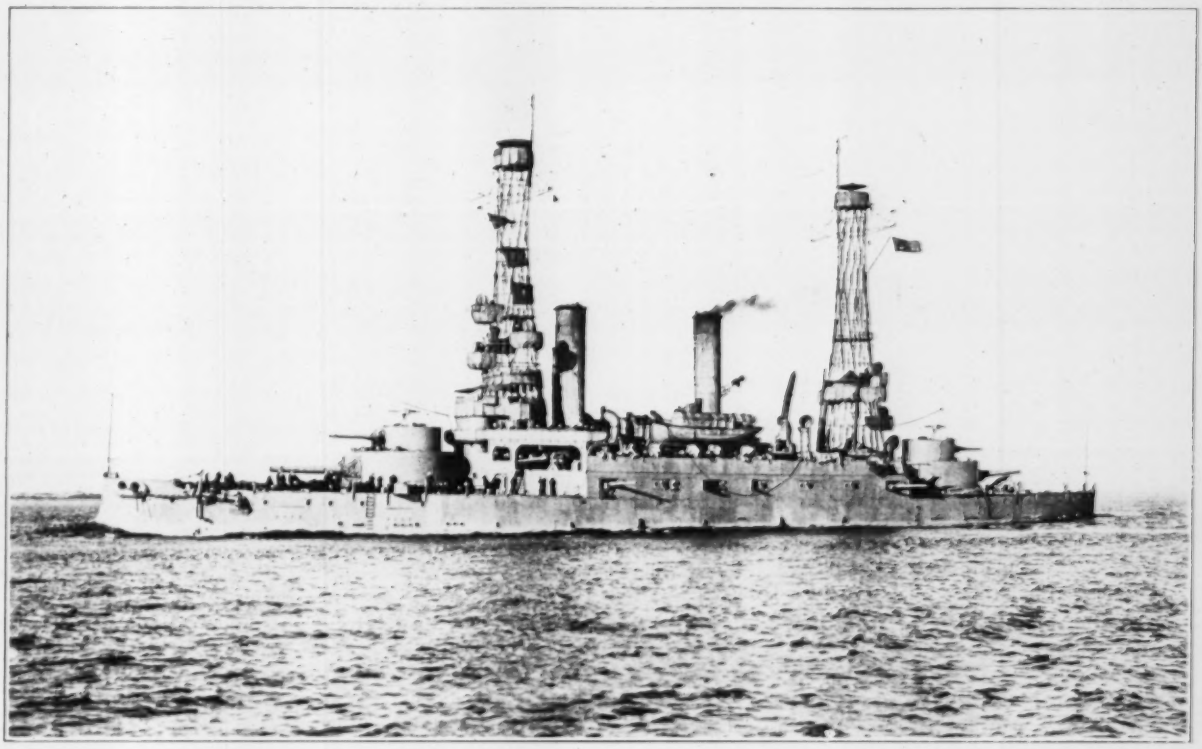

FIG. 4

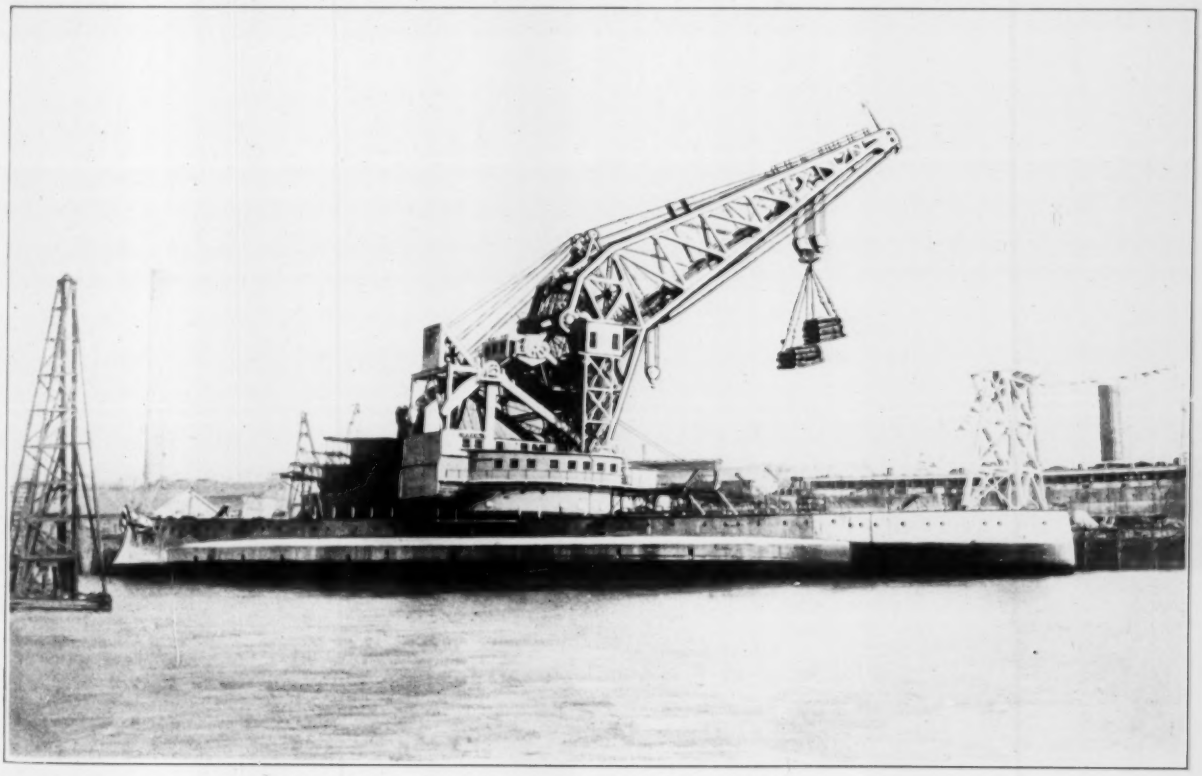

FIG. 5

In Its Naval Career the "Kearsarge" Has Played Two Roles

Fig. 4 shows the *Kearsarge* as a battleship in active service. Fig. 5: Rebuilt into U. S. Navy Crane Ship No. 1 mounting a 250-ton revolving crane the *Kearsarge* is handling a full load under test. Note the cradle at the stern of the ship in which the jib is held while at sea, and the bulge to increase the ship's beam. The auxiliary hoist appears at the lower end of its trolley on the jib.

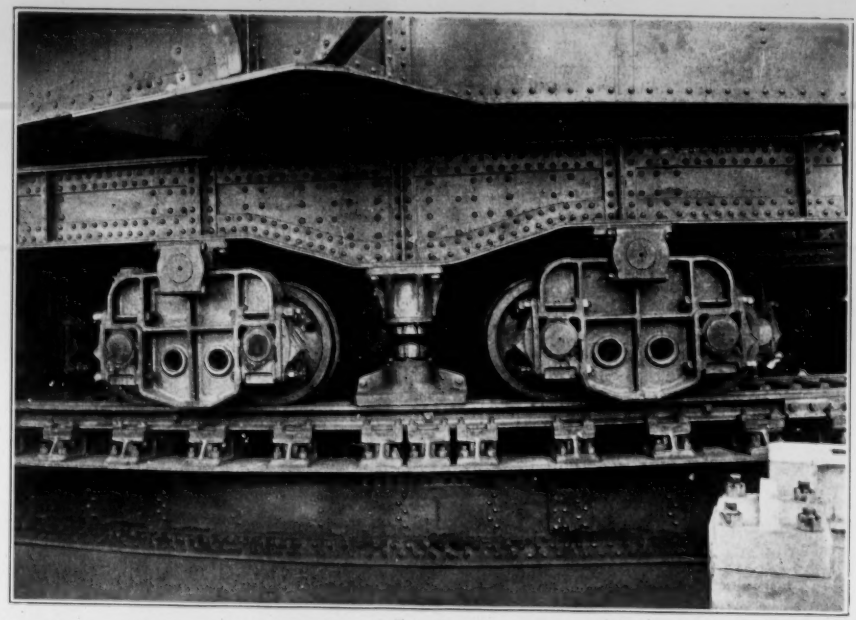

Fig. 6

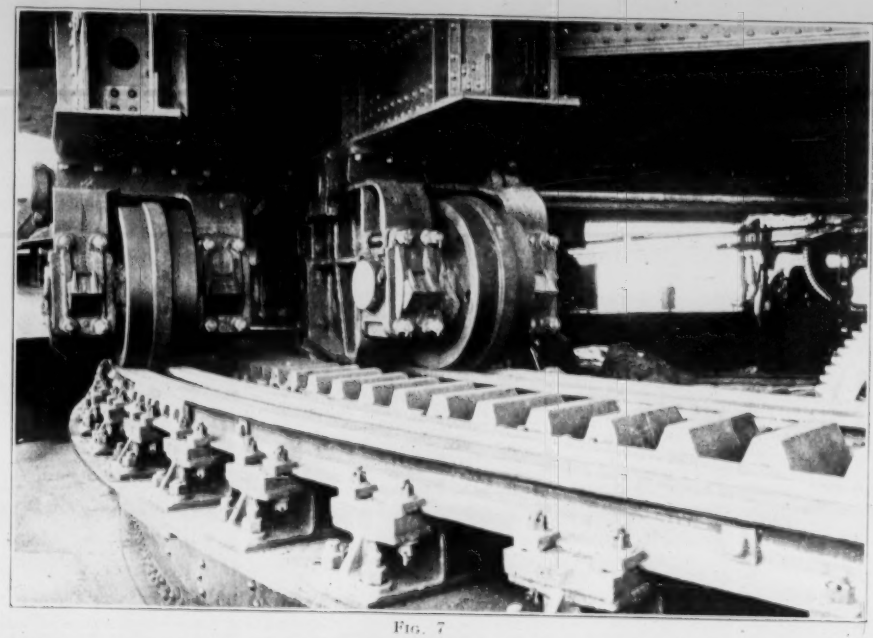

Fig. 7

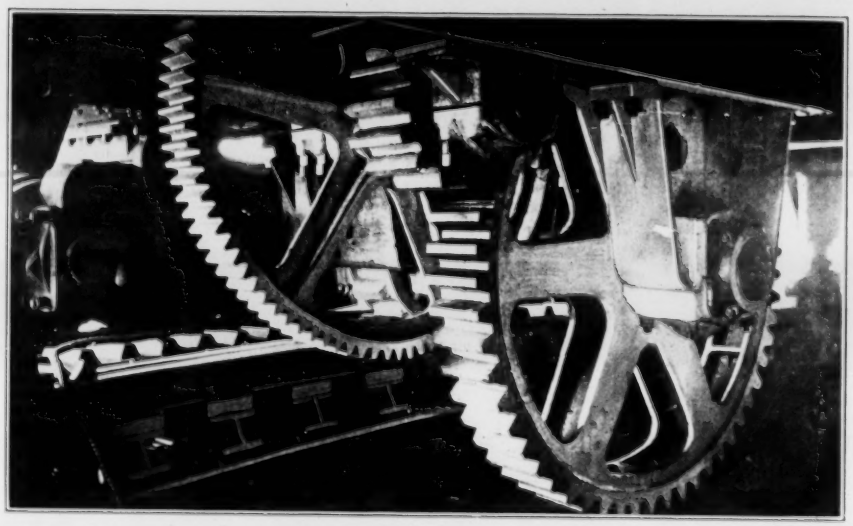

Fig. 8

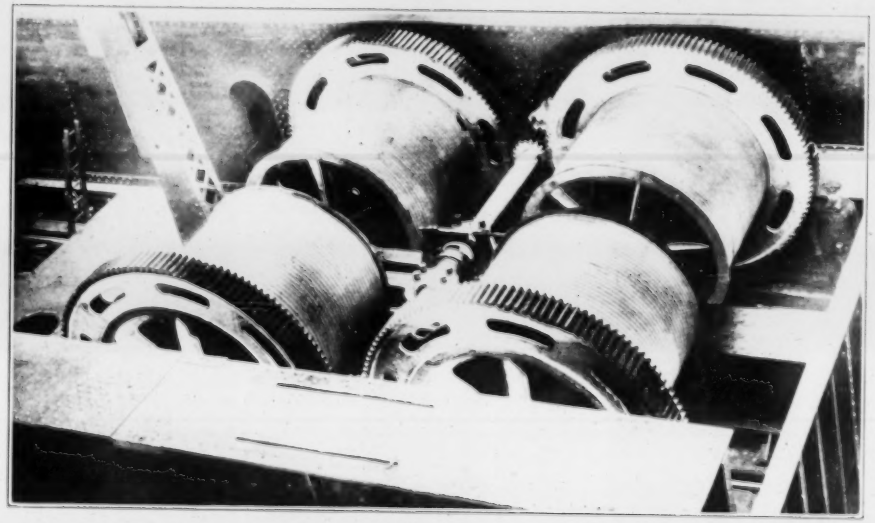

Fig. 9

Details of Design Are Rugged

Figs. 6 and 7 show the interesting method of supporting the crane superstructure. Fig. 6 makes especially clear the equalizing action of the supports which enables the crane superstructure to conform to any deflection in the track. The important lifting jack for use when jib is cradled is also shown between the two trucks. In Fig. 7 the conical rollers are displayed as is the rack through which the rotating mechanism operates. The gear train and part of the rotating mechanism are shown in Fig. 8 while in Fig. 9 the large hoisting drums may be seen.

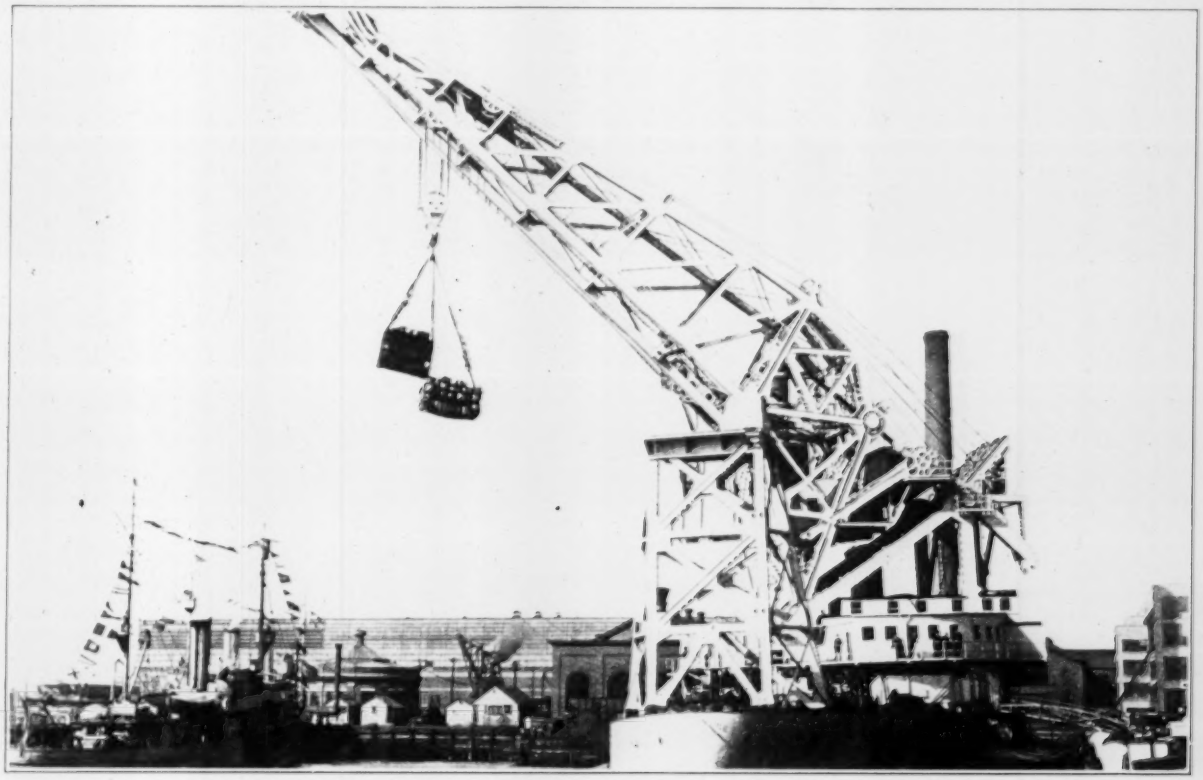

FIG. 10

FIG. 11

The Crane Ship Operates Under Widely Varying Conditions

The crane ship can handle 250 tons at 101 ft. radius from the center of rotation. Fig. 10 shows this with the ship on even keel. Using the auxiliary hoist the crane can handle 50 tons at 173 ft. radius with the hoist at the extreme end of the trolley. Fig. 11 shows this and also the two main hoists of 125 tons each, which can be used together to handle 250 tons. Fig. 10 shows the jib nearly at its highest position, while in Fig. 11 the jib is nearly horizontal.

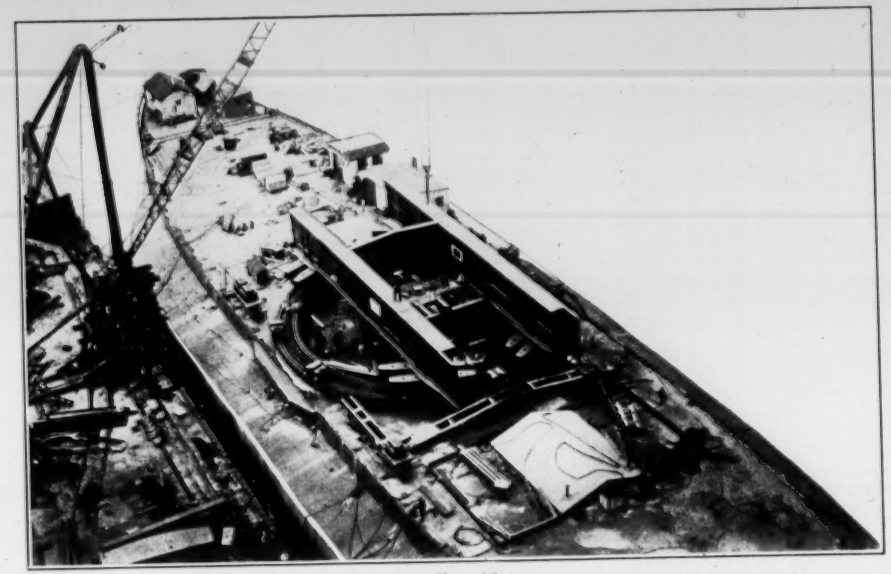

Fig. 12

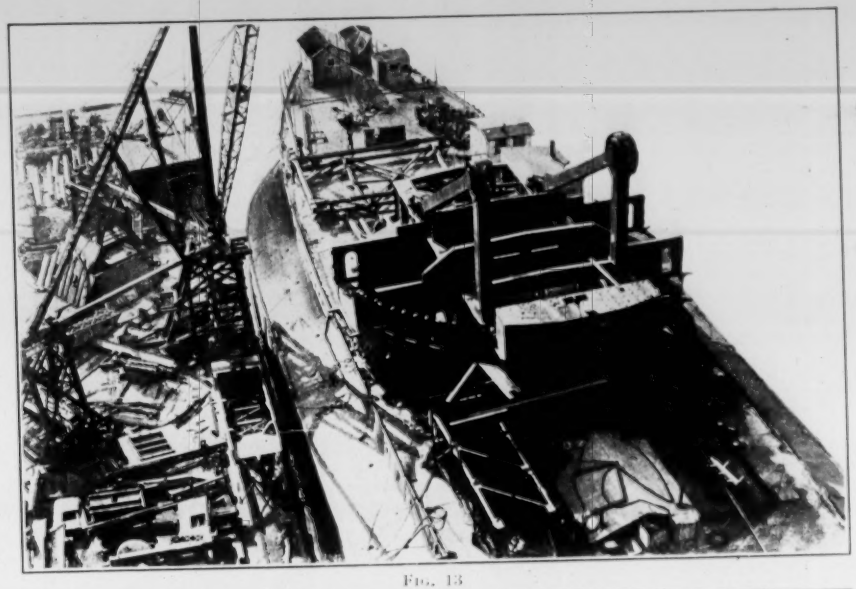

Fig. 13

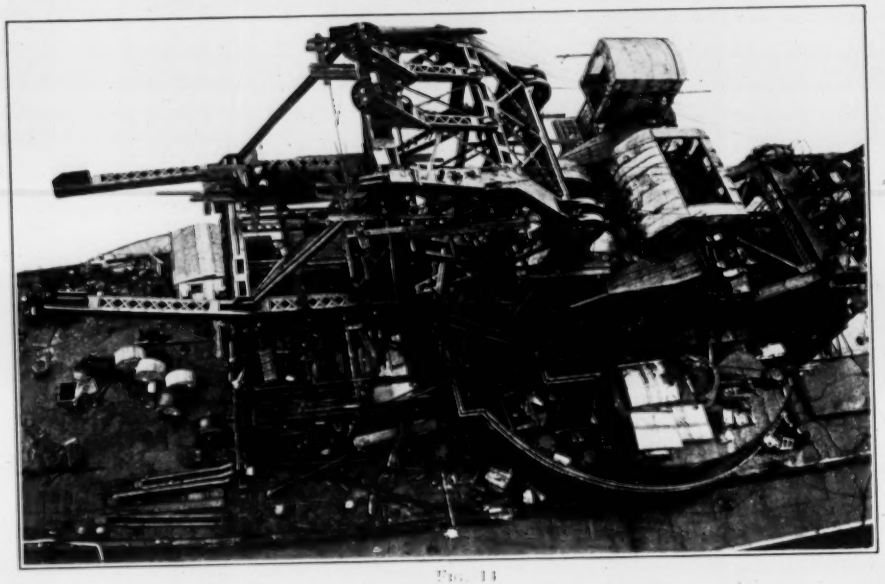

Fig. 14

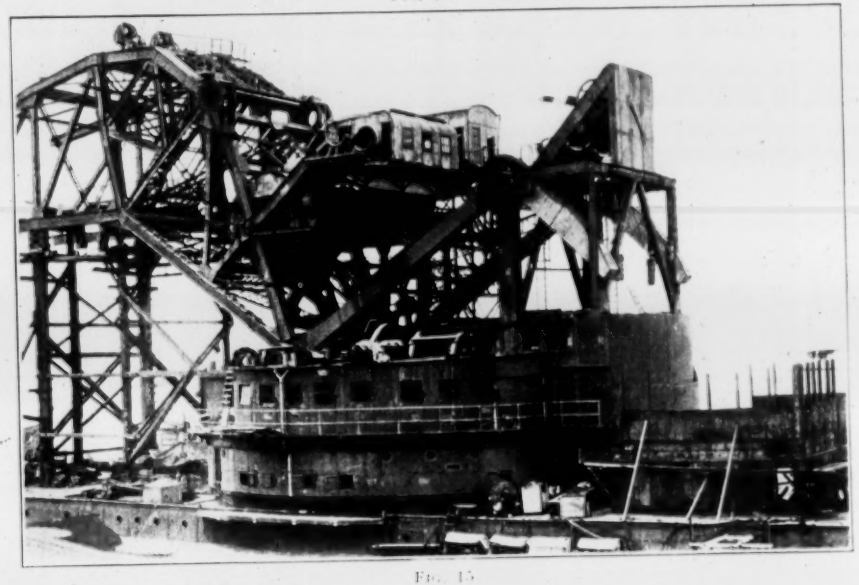

Fig. 15

Erection Pictures Show Fundamentals of Design

Fig. 12 (January 3, 1922). The foundation frame of the superstructure is built of two girders, each resting on four equalizing girders—a pair under each end. Details of the latter are shown in Figs. 6 and 7. Fig. 12 also shows two trucks placed on the outer circular track on each side of the main frame. These four trucks are for support of the outrigger girders shown at right angles to the foundation girders in Fig. 13 (January 24, 1922). Note the widening effect of the hull bulges in these two figures. Figs. 14 (March 31) and 15 (May 31) show the construction of the jib well under way. The hoisting machinery is being used to bring the jib members into position.

The Navy specifications demanded that the crane should be capable of withstanding the roll of a ship of the order of 25 deg. complete in 3 sec., which imposed on every part of the structure an enormous strain. Furthermore, this was to be a seagoing unit, which meant that it might have to encounter rough weather. Every part, therefore, had to be cradled in such a manner that when the vessel was traveling in the open sea there would be no pounding—not an easy proposition with a structure in excess of 40 ft. high above the deck level and weighing millions of pounds. Finally, the crane had to operate on a circular track of 60 ft. mean diameter in a floating structure, that is, one inevitably subject to distortions, and yet remain under perfect control. The whole structure was so large that the manufacture of parts which otherwise would have been merely a matter of routine became a serious engineering problem in itself.

To give but one instance, luffing screws had to be made in sizes 15 in. in diameter and 28 ft. long, while the nuts for them were 5 ft. long, 26 in. in diameter, and about 5000 lb. each in weight. It was a man-sized job to handle parts of this character, and it is a high testimonial to American engineering that every detail of the crane was designed and manufactured in the United States—not because there were any restrictions imposed as to the procurement of parts abroad, but because facilities were available here to do everything to the complete satisfaction of the parties involved, and with excellent success as the tests have shown.

Design and Construction of the Crane

The *Kearsarge* crane is of the luffing-jib type and is so designed that the jib may be lowered to rest in a cradle at the stern of the ship. (Fig. 1.) In view of the great weight of the crane and the fact that it was to be installed on a seagoing vessel, it was very important to arrange it so that it would be in a perfectly steady position while the ship was under way. To provide for this the crane when not in use is supported at three points. In the first place, it is securely held in the cradle just referred to, which is a substantially built tower. Next, it is held by the center pin about which it rotates; and finally in the rear, back of the rotating track and under the counterweight, there is a heavy pin held in a rigidly constructed frame. The whole structure is such that the jib cannot move notwithstanding the rolling of the ship. The crane is provided with four hooks, two of 125 tons lifting capacity each, one 250-ton compensator-type hook, and a light 40-ton hook on a special trolley for emergency work. Special cradles are provided for these hooks so that when the ship is under way there are no swinging parts.

The operating equipment of the crane consists of two main hoists of 125 gross tons capacity each, operated by separate motors and so arranged that they may be coupled together when handling the maximum load of 250 tons. For this purpose an equalizer is provided which carries a 250-ton hook and is connected by heavy pins to the hooks of the 125-ton blocks. (Fig. 16.) In actual tests 312 tons were lifted, equivalent, roughly, to the weight of 4500 persons. These blocks are suspended by ropes passing over sheaves located at the fixed point of the jib, the reach being varied by luffing the jib.

The Foundation

The crane foundation is formed by a circular box girder having concentric web plates spaced 4 ft. apart with a mean diameter of 60 ft. This girder is securely built into the hull of the ship and a top flange projects about 2 ft. above the deck and is provided with a heavy cover plate forming a plane surface upon which the crane runway is mounted. This runway consists of four rings of 150-lb. rails spaced in pairs over the webs of the foundation girder. The rails are supported on cast-steel radial chairs secured to the girder and provided with wedges so that the elevation of the rails may be properly adjusted. In order to permit the rotation of the crane about its center pin without undue friction, the rails are so elevated that the centers of their heads are located on the elements of two cones having their apex at the center of rotation.

The usual method of operating cranes of this type is by rollers. In this case, however, the diameter of the runway was so large and the loads carried so great that it would have been impossible to retain the rigidity of the track necessary for roller operation. Because of this, a novel construction was evolved, the crane rotating on double-tread cast-steel wheels approximately 30 in. in diameter with treads finished to diameters corresponding to the rolling cones, one side of the cone being, of course, somewhat higher than the other, with a corresponding variation in the elevation of the treads on the track. This may be seen from Figs. 6 and 7 which show the wheels. The wheels are arranged in pairs with each pair carried in a cast-steel equalizing-truck frame forming a truck unit. Between the trucks are provided powerful jacks capable of supporting the weight of the entire structure. When the crane is in operation the jacks are, of course, lifted off the track. When the ship is under way at sea and the crane is cradled the jacks support the weight of the structure and thus relieve the wheels from possible pounding in a rough sea, which result in the production of flats.

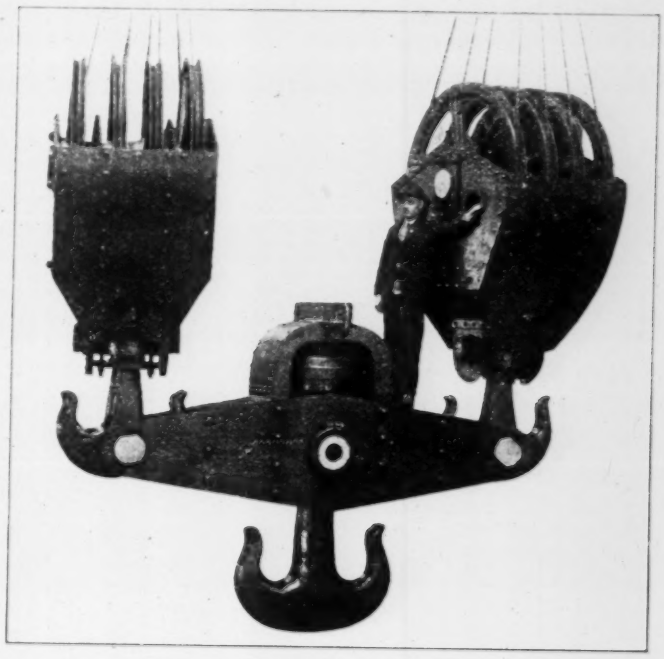

FIG. 16 WITH AN EQUALIZER, THE MAIN HOISTS HANDLE 250 TONS

The main structure of the crane is built upon two box girders which are 10 ft. deep and 75 ft. long, and have webs spaced 30 in. apart. These girders are supported by the main carrying trucks, four fully equalized units being located under each end of the girders. Intermediate between the main trucks are spring-mounted truck units which are adjusted to take a part of the maximum truck load. Outrigger girders normal to the sides of the main girders are supported over four truck units for the purpose of securing side stability. The center-pin girder is built between the main girders and extends to within 2 ft. of the deck. The center pin is secured in this girder and turns in a bearing mounted in a companion girder built into the ship's hull. The center pin is hollow and the electric conductors supplying power for crane operation pass up through it to rings on the contact column above, from which the current is taken off by brushes.

The counterweight compartment is built between the main girders at the back and contains about 1,000,000 lb. of armor plate secured in place by concrete. This counterweight is proportioned so that the reverse movement with the light jib in its high position is approximately the same as the forward movement with maximum load at full reach. Back stays are built at the rear of the main girders for the purpose of supporting the back luffing nuts. These stays also serve as a support for the hoist-rope sheaves.

All the machinery for hoisting and rotating is carried by the main and outrigger girders and is completely enclosed by a circular machinery house which extends below the top of the crane foundation to form a skirt so constructed as to prevent the seas from washing over the trucks or foundation.

The Luffing Mechanism and Its Operation

From its lowest position when resting in the cradle to its highest working position the jib revolves about its hinge pins through an angle of nearly 60 deg. This movement is accomplished by large luffing screws operating through the upper and rear nuts previously mentioned. The screws are made of chrome-nickel steel and are 15 in. in diameter and 28 ft. long. Two of these screws are coupled together at the center, one having right-hand and the other left-hand threads so that their rotation tends to increase or diminish the distance between the nuts according to the direction in which they are turned. The threads of the screw are of the buttress type, 4 in. pitch, and the maximum load carried on each screw is 500 tons, which occurs with the load at maximum reach.

The design of these luffing screws was anything but an easy problem. The screws are exposed to such enormous stresses that very great strength had to be put into them and at the same time their size had to be held down as much as possible in order to reduce the weight of the screw and the size of the luffing nuts, of which more will be said later. Furthermore, the forging of a piece 28 ft. long was a difficult proposition in itself, and any increase in diameter would have materially increased the difficulty of forging. After certain tests chrome-nickel steel was selected and its use made it possible to keep the diameter of the screw down to 15 in.

Special manganese bronze is used for the luffing nuts which are about 5 ft. long, 26 in. in diameter, and weigh about 5000 lb. each. Each nut is enclosed in a cast-steel housing with trunnions turning in bearings attached to the boom and the back stay, and the design is such that when the jib is at rest on the cradle the lower nut trunnion may be slacked off, relieving the load on the screws and avoiding the possibility of excessive tension which might be produced by the deflection of the ship in a seaway. The selection of the material for these nuts was not easy, as, for obvious reasons, steel could not be used. We are informed that the bronze finally chosen has the following physical characteristics:

Ultimate strength	100,000 lb.
Yield point	60,000 lb.
Elongation	24 per cent
Brinell hardness	165

Operation of the luffing screws is controlled by a cross-shaft geared to the screw couplings by bevel gears. This shaft is turned by a spur-gear reduction to the intermediate shaft, which in turn is connected to the motor by herringbone gears. This mechanism is mounted on a machinery floor carried by a luffing strut which is pivoted to the jib midway between the jib hinge and upper luffing nut. (Fig. 17.) This strut also pivots on a large housing which encloses the screw coupling and the bevel gears midway between the upper and lower nuts.

The strut thus located forms a bisector of two legs of the triangle formed by lines joining the luffing nuts and the jib hinge, and it always maintains the same angle with the horizontal in all positions of the jib; this condition lends itself to the arrangement of the luffing mechanism as the floor of this machinery house is thus maintained horizontal at all times. This fact is also true of the auxiliary trolley mechanism, which is supported by the strut. However, on account of the fact that the relative positions of the strut and the jib are constantly varying, it is necessary to locate the trolley drum on the center of the lower pivot of the strut, which is of course a point common to both. In this location no change in length of the trolley ropes results as the jib traverses its entire range.

The maintenance of the floor of the machinery house at all times in a horizontal position as referred to above is secured in the following manner: The luffing strut at its upper end is provided with a bearing engaging trunnions on the bevel-gear housing in which the coupling for the upper and lower screws is located. This coupling is used for connecting the upper and lower screws, right and left hand, respectively, and the nuts through which the screws turn are located at equal distances on either side of the housing trunnions.

The screws are revolved to luff the jib and it is evident that any revolution of the screws through the nuts increases or diminishes the center distance. At the same time the coupling retains its position midway between the nuts. The lower end of the luffing strut is secured by pins to the jib at a point midway between the forward and upper luffing nut and the jib hinge. On account of the fact that the two points of support of the strut are always midway between the points which vary in the course of the luffing function, the strut always remains parallel to the third side of the triangle which is formed by these points, the third side in this case being the backstay. It is therefore evident that any structure forming a part of the strut or built into the strut will maintain a constant angle with the backstay or any portion of the stationary part, and thus will be maintained in a permanent angular relation to the deck.

All the functions of the crane are controlled by one operator, the various levers for this purpose being located in an elevated cab at one side of the jib.

U. S. CRANE SHIP NO. 1—GENERAL DATA

	Battleship	Crane Ship
Length	368 ft.	368 ft.
Beam	72 ft. 2½ in.	92 ft.
Draft	23 ft. 6 in.	19 ft. 7 in.
Displacement	11,520 tons	10,350 tons
Speed	16 knots	11 knots
No. of vertical triple-expansion engines	2	1

SPEEDS OF HOISTS

Main hoist loaded	6 ft. per min.
Main hoist empty	16 ft. per min.
Auxiliary hoist loaded	15 ft. per min.
Auxiliary hoist empty	30 ft. per min.
Auxiliary trolley	50 ft. per min.
Luffing from high to low position	25 min.
Rotating one revolution	9 min.

RANGES OF OPERATION

Main Hoists:

Radius: Between 72 ft. and 101 ft. from center of rotation.

Vertical Range: From 103 ft. above to 40 ft. below rails on which crane revolves.

Auxiliary Hoist:

At 114 ft. radius the auxiliary hook has a vertical range from 135 ft. above the rails to 40 ft. below. With the jib in its highest position the upper vertical range of the auxiliary hoist is increased to 147 ft. at 91 ft. radius, and the maximum reach with the jibs in a horizontal position is approximately 173 ft. from the center of rotation. The maximum range of the auxiliary hoist is 175 ft.

Prevention of Accidents Due to Rolling of Ship

One of the important problems in the design of this crane was to so proportion its members that they would not only sustain the working load but would withstand the strain and impacts resulting from the rolling and pitching of the ship when at sea, and elaborate means are provided to protect the machine from any damage arising from this cause.

Heavy jackscrews are provided between the truck units. These jacks may be set to relieve the wheel loads and prevent pounding which might result in flat wheels. Each side of the crane has large turnbuckles for securing the crane structure to the hull, and the rear of the crane is provided with a socket into which a forged-steel locking pin is inserted to prevent the rotation of the structure as the ship rolls from side to side. The cradle in which the jib rests is fitted with heavy steel shoes and provided with clamps for holding the jib in position. A cradle is also provided for receiving the hoist blocks and equalizer when not in use.

The Hoisting Machinery

The main hoist machinery consists of two units, each having a capacity of 125 gross tons. The drums (Fig. 9) forming a part of this mechanism are 86 in. in diameter and 8 ft. 4 in. long arranged in tandem, each drum being provided with a driving gear meshing with a common pinion carried on a shaft between the drums.

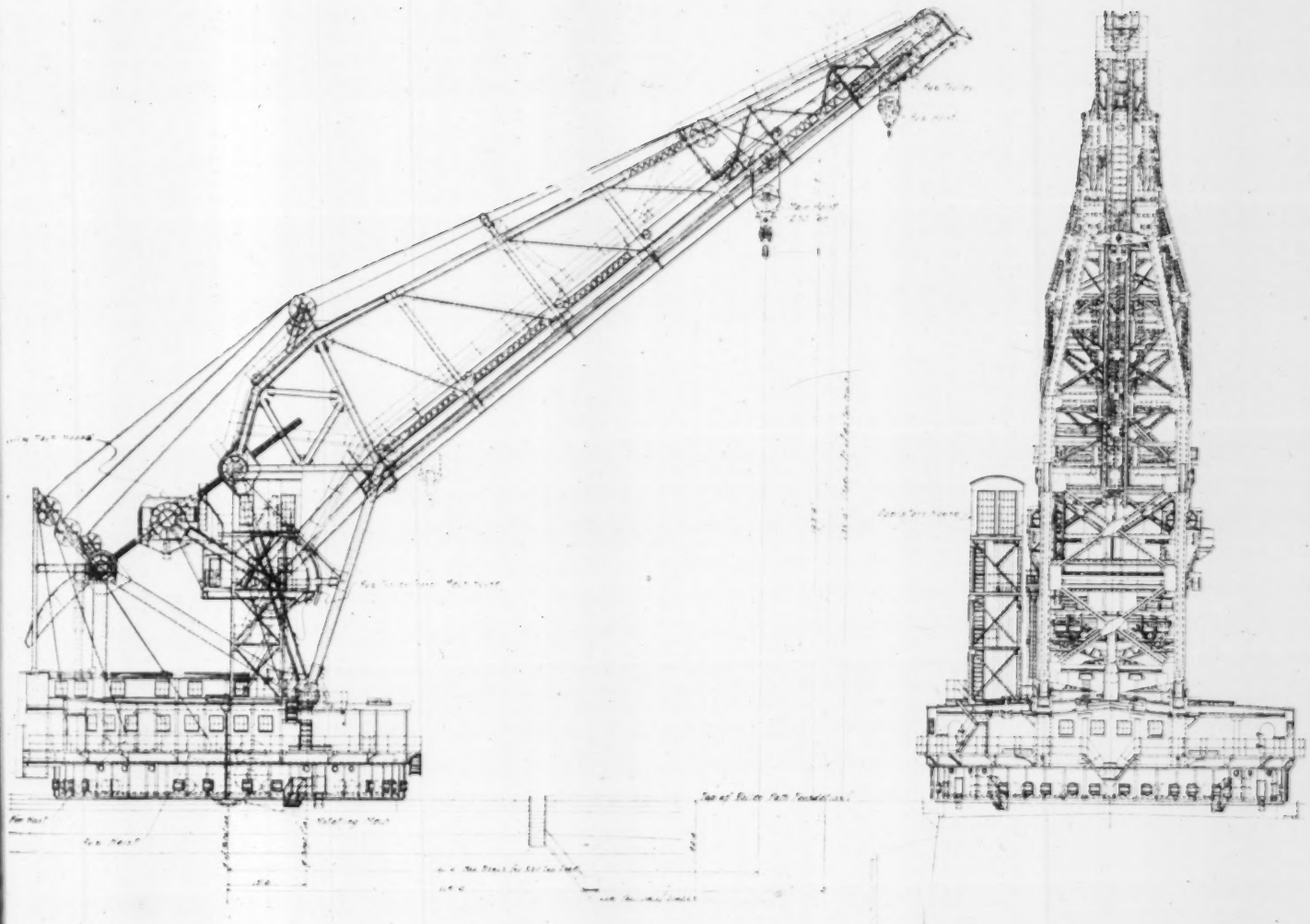

FIG. 17 THE CRANE DESIGN INVOLVES SEVERE PROBLEMS

Severe mechanical and structural problems were involved in the design of a crane to handle over three hundred tons on the main hoist and fifty tons on the auxiliary hoist between the limits shown in Fig. 17. Note particularly the isosceles triangle with the jib post as one of the equal sides, the inclined foundation member as the other, and the luffing screws as the base. The connection between the middle point of the jib post and the luffing nuts is always parallel to the inclined foundation member, and the floor of the luffing mechanism house is always horizontal.

The drums and driving gears of these units are located between the main gears of the crane. The drums stand on their supporting shafts which are carried in bearings secured to a common bed plate. This bed plate is in turn carried by a substantial structural foundation built into the crane structure.

The pinion shafts of the two hoist units are in accurate alignment and a jaw clutch is provided at the center to connect the two units when handling the 250 tons on the equalizer.

Midway between the curved rails upon which the trucks travel is a bevel-gear rack used for rotating the crane. (Fig. 7.) The pitch diameter of this rack is 61 ft. The teeth are 20 deg. involute in form and have a pitch of about 9 in. The rack is made in sections which are bolted to the rail chairs.

Meshing with the rack are two pinions located diametrically opposite at each side of the revolving structure. (Fig. 8.) These pinions have 12 teeth 20 deg. involute in form and are half-shrouded. They are keyed to separate shafts which are driven through two reductions of spur gears and a motor train of cut herringbone gears by a 110-hp. General Electric motor. The motor and first intermediate shaft are mounted on a cast-steel bed plate in the machinery house, while the second and third shafts are below the floor girders. Each motor pinion is fitted with a magnetic disk brake and connected to the motor by a flexible coupling. Double-acting equalized post brakes are provided on each unit operated by a single lever in the cab. There is no mechanical connection between the two rotating units, as the series characteristics of the motors equalizes the load on the two pinions.

Although the motor brakes when set will normally resist any tendency to rotate, as an additional precaution a heavy locking pin is provided which is inserted by a hand-operated mechanism into a socket in the under side of the counterweight compartment at the rear of the structure. This pin is of forged steel 14 in. by 12 in. and is operated by a screw-toggle arrangement and a hand-wheel. The mechanism is located in the transverse girder attached to the deck of the ship, and of such a height that the rotating structure just clears in passing.

Four 4-in. turnbuckles are provided at the outer ends of outrigger girder. When the crane is not working or preparing for a sea voyage, these turnbuckles are secured to socket castings attached to the crane foundation to prevent any movement when the ship is rolling.

The luffing mechanism is located in a house built into the upper end of the luffing strut between the screws. The upper end of the strut is provided with heavy strap castings which surround trunnions on the bevel-gear housings. These housings are made in halves and enclose the bevel gears and pinions which turn the luffing screws. The bevel gears are bolted to flanges of nickel-steel couplings, used to connect the upper and lower luffing screws, which are tightly fitted into sockets in the ends of the couplings and secured by wedged keys. The screws are 15 in. in diameter and have a 4-in. pitch thread. One right-hand and one left-hand screw are used on each side of the crane for luffing the jib. The combined length of the two screws and their coupling is 83 ft., and their weight about 45,000 lb. The lower base of the housing forms a thrust bearing against a shoulder on the coupling to maintain the luffing strut in position.

The bevel pinions driving the coupling gears are keyed to opposite

(Continued on page 399)

Orifice Coefficients—Data and Results of Tests

By JACOB M. SPITZGLASS,[1] CHICAGO, ILL.

This paper discusses the results of experimental work conducted at the Research Laboratory of the Republic Flow Meters Co., of Chicago, on the use of orifice plates for measuring the flow of fluids in pipes.

Extensive tests were carried on for a period of several years to determine the effect of the varying factors such as the orifice ratio, the size of the pipe, and the distance of the upstream and downstream connections upon the pressure difference across the orifice plate. The tests were conducted on seven sizes of pipes, from 2-in. to 12-in. standard. Fourteen orifice ratios were used in each size and twelve connections were tested on each side of the orifize plate.

The tests were made on the flow of atmospheric air, supplied by a Sturtevant blower driven by a 15-hp. motor and having a maximum capacity of 6000 cu. ft. per min., at a pressure of 10 in. of water. To vary the velocity of flow, an adjustable air gate was attatched to regulate the intake to the blower. The air passing through the orifice was measured by five calibrated impact tubes ranging from 1 in. to 4 in. in internal diameter.

The theoretical relations of the functions are given briefly, preceded by definitions of the terms involved. The paper includes a number of tables and a collection of characteristic curves that may be employed for determining the flow through orifice plates in a given size of pipe.

IT HAS been long established in the literature of mechanical engineering, and especially in the various textbooks on hydraulics, that a stream of fluid issuing from a rounded aperture in the wall of a large vessel can be gaged accurately by the difference in static pressure between the inside and the outside of the vessel containing that fluid.

The relation between the pressure difference and the velocity of the jet issuing from the aperture has been derived theoretically for jets flowing into the open atmosphere and also for jets submerged under a lower head of the same fluid. It has been established by numerous experiments that upon leaving the vessel the cross-section of the stream is gradually reduced in area until, at a

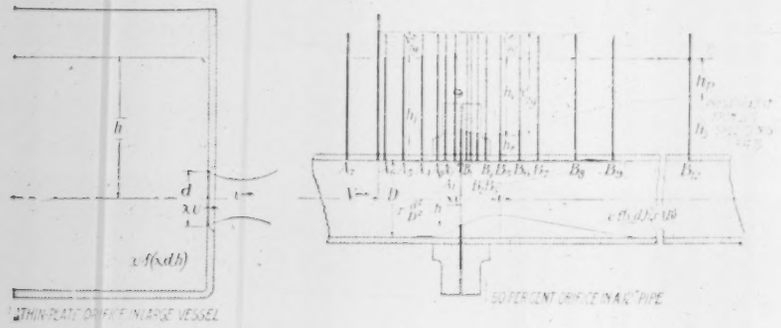

FIG. 1 THIN-PLATE ORIFICE—JET CONTRACTION AND PRESSURE GRADIENT

point known as the vena contracta, it is only about 60 per cent of the actual area of the aperture in the wall of the vessel. This contrivance used as a device for measuring the flow of fluids has been termed the "frictionless" or "thin-plate" orifice.

Recently the principle of the thin-plate orifice has been successfully applied to measuring the flow of fluids in pipes by the drop of pressure through the restricted area of an orifice plate placed between two flanges of the given pipe. At first the practice was limited entirely to cases where the area of the opening was much smaller than the cross-section of pipe, so that they could be considered as being similar to the submerged aperture in the wall of a large vessel. Further developments in this application have necessitated the use of larger-ratio orifices, which obviously differ from the case of the jet issuing from the large vessel, and therefore cannot be treated in the same manner. A comparison of the two cases with reference to Fig. 1 brings out the following points of difference:

First, in the case of the thin-plate orifice in the large vessel, the velocity of the jet issuing from the wall represents the equivalent of the hydrostatic head or pressure above the center of the opening, since the fluid in the vessel may be considered to be at rest. In the case of the pipe orifice it is the increase in velocity over the velocity of approach that is equivalent to the differential head across the orifice. This item may be termed the effect of initial velocity in the pipe.

Second, in the case of the pipe orifice the formation of the stream may be greatly affected by the proximity of the walls of the pipe both on entering and on leaving the orifice. In the case of the large vessel this effect is eliminated on either side of the orifice and the stream of the fluid can be freely formed into the natural contraction of the issuing jet. This item may be termed the effect of the size of the pipe or of the proximity of the walls.

FIG. 2 INTERIOR OF RESEARCH LABORATORY

Third, in the case of the large vessel the pressure difference affecting the flow of the fluid is fixed by the difference between the pressure inside and outside the vessel. In the case of the pipe orifice it is necessary to obtain the pressure difference between a point ahead of the orifice where the current is parallel to the walls of the pipe and a point beyond it where the jet has been fully contracted, in order to have the true equivalent of the increased velocity pressure of the jet. This may be termed the effect of shifting the pressure taps on either side of the orifice.

These given points of difference are demonstrated graphically in Fig. 1 to show their relations to the dimensional quantities involved. Thus, the effect of initial velocity is a function of the relation between the velocity V of the fluid in the pipe and the velocity v of the jet at the point of greatest contraction, or of the ratio d^2/D^2 between the cross-sections, which, in its turn, is a function of the jet contraction x and of the ratio between the cross-section of the orifice and the cross-section of the pipe. The effect of restriction or the proximity of the walls is a function of the distance between the wall of the pipe and the edge of the opening, which, in its turn, is a function of the diameter D of the pipe for any given orifice ratio. The effect of shifting the pressure taps is necessarily a function of the location of the taps on the A and B sides of the orifice plane.

The experimental work described in the complete paper was undertaken with the object of obtaining the necessary data for this analysis; namely, to determine by actual tests the effect produced in the pipe orifice, used as a flow-measuring device, by the variation of the orifice ratio, by changing the size of the pipe, and by shifting the pressure taps on either side of the orifice plate.

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Contributed by the Research Committee and presented at the Annual Meeting, New York, December 4 to 7, 1922, of THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS. Abridged. All papers are subject to revision.

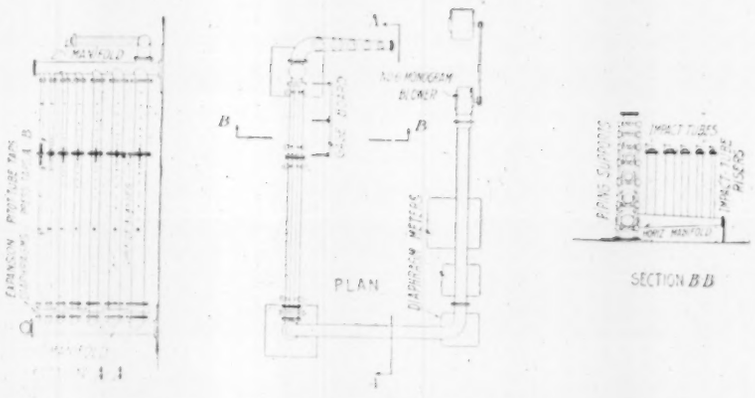

FIG. 3 GENERAL LAYOUT OF RESEARCH LABORATORY EQUIPMENT

THE TESTS

In the early part of 1919 the engineering department of the Republic Flow Meters Company began its first series of orifice tests on several sizes of pipes. On the removal of the company to its new headquarters in 1920, a research laboratory was established on the second floor of the factory building for the purpose of furthering the experimental work on orifice coefficients. Fig. 2 is a view of this laboratory and Fig. 3 shows the general arrangement of apparatus as originally installed.

Extensive tests were carried on to determine the effect of the varying factors such as the orifice ratio, the size of the pipe, and the distance of the up-stream and down-stream connections upon the pressure difference across the orifice plate. The tests were conducted on seven sizes of pipes, from 2-in. to 12-in. standard. Fourteen orifice ratios were used in each size and twelve connections were tested on each side of the orifice plate.

The tests were made on the flow of atmospheric air, supplied by a Sturtevant blower having a maximum capacity of 6000 cu. ft. per min. at a pressure of 10 in. of water. The air passing through the orifice was measured by five calibrated impact tubes ranging from 1 in. to 4 in. in internal diameter. A detailed account of the calibration of the impact tubes is given in the complete paper, as well as curves showing the coefficient as a function of the impact head through the tube. The arrangement of the installation for the final tests is also described and illustrated in detail, and an account is given of the method of testing the various orifices.

THEORETICAL RELATIONS OF FUNCTIONS

The following notation is adopted with reference to Fig. 1, in which most of the quantities and dimensions are demonstrated diagrammatically.

d = diameter of the thin-plate orifice, either in the restricted pipe or in the wall of the large vessel
D = diameter of pipe
x = percentage of jet contraction at the smallest cross-section or the vena contracta of stream
r = ratio of orifice cross-section to pipe cross-section, or $d^2 : D^2$; xr = ratio of vena contracta to cross-section of pipe
$\rho = 1 : r$ = ratio of pipe cross-section to orifice cross-section or $D^2 : d^2$; $\rho\, x$ = ratio of pipe cross-section to the vena contracta of stream
A = distance from plane of orifice to upstream pressure taps
B = distance from plane of orifice to downstream pressure taps
h_1 = static pressure at section of normal flow ahead of orifice
h_2 = static pressure at section of vena contracta
h_3 = static pressure at section of normal flow beyond orifice
h = differential head between any two points on opposite sides of the orifice
h_i = differential head between the two points designated as h_1 and h_2. This quantity represents the pressure drop across the orifice corresponding to the increased velocity of the flow
h_p = differential head between the two points designated as h_1 and h_3. This quantity measures the total loss of pressure caused by the sudden contraction and expansion of the flow through the orifice
Z = ratio of h_p to h_i
V = velocity of fluid at section of normal flow in pipe
v = velocity of fluid at vena contracta of stream
xv = velocity of fluid at section of orifice
Q = rate of flow or amount of fluid passing through the orifice in a given unit of time
C = coefficient of discharge defined by—

$$Q = C \frac{\pi}{4} \frac{d^2}{\sqrt{1 - r^2}} \sqrt{2gh} = C \frac{\pi}{4} \frac{D^2}{\sqrt{\rho^2 - 1}} \sqrt{2gh} \quad [1]$$

C' = velocity coefficient of orifice defined by—

$$v = C' \sqrt{2gh}, \text{ and } C' = f(A) f(B) \sqrt{\frac{1}{1 - x^2 r^2}} \quad [2]$$

(xC') = orifice coefficient defined by—

$$Q = (xC') \frac{\pi}{4} d^2 \sqrt{2gh} \quad [3]$$

C'' = orifice coefficient defined by—

$$Q = C'' \frac{\pi}{4} D^2 \sqrt{2gh}, \text{ or } C'' = (xC')r \quad [4]$$

Derivations of Equations [1] to [4] defining C, C' and C'' are given in the complete paper. Subscript v, with reference to the given terms, applies to the condition of pressure tap A at normal flow ahead of the orifice plane and pressure tap B at the vena contracta. Subscript p applies to the condition of pressure tap A at normal flow ahead of the orifice plane, and pressure tap B at normal flow after the orifice plane.

The quantity C in Equation [1] is the coefficient of discharge for the orifice as compared with the coefficient of discharge for the venturi tube. In using this coefficient it is always necessary when solving Equation [1] to compute the radical $\sqrt{1 - r^2}$ for the given orifice ratio. This is especially troublesome when a solution is sought for the size of the orifice necessary for a given differential and amount of flow, as it involves two unknown quantities C and

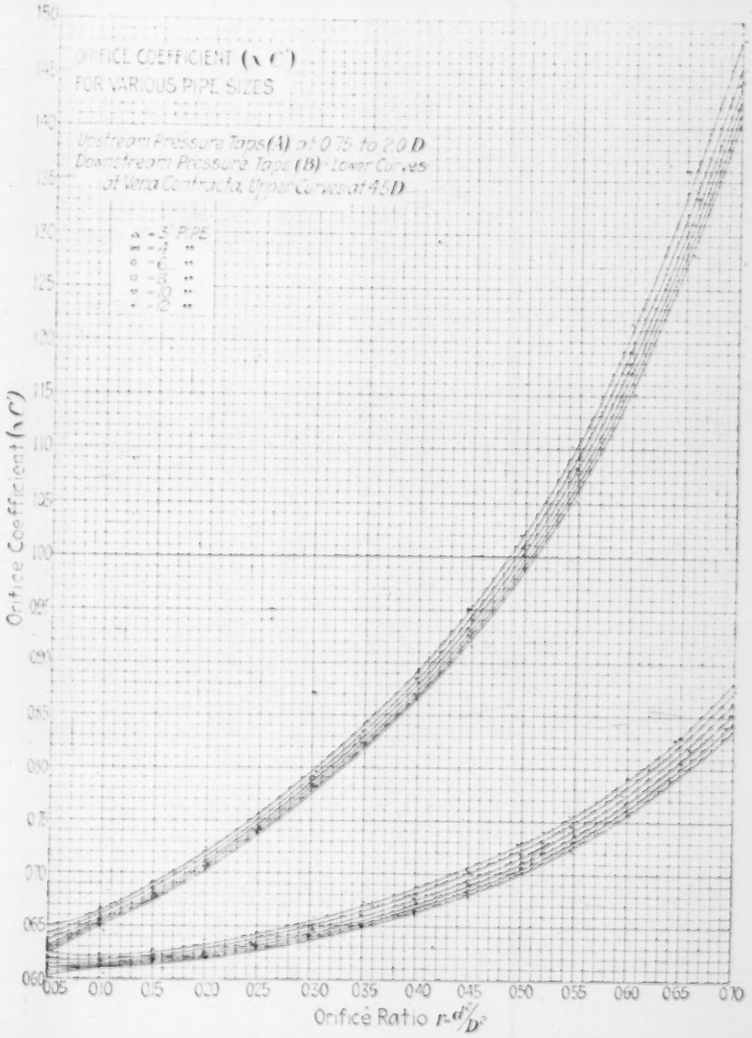
ORIFICE COEFFICIENT (xC)
FOR VARIOUS PIPE SIZES
Upstream Pressure Taps (A) at 0.75 to 2.0 D
Downstream Pressure Taps (B)—Lower Curves at Vena Contracta, Upper Curves at 4 D
Orifice Coefficient (xC)
Orifice Ratio r = d²/D²

FIG. 4 ORIFICE COEFFICIENTS FOR VARIOUS PIPE SIZES

r. To overcome this difficulty, a modification of Equation [3] is employed with reference to the cross-section of the pipe. Since $d^2 = D^2 r$, we can write—

$$Q = (xC')r\,\frac{\pi}{4}\,D^2\sqrt{2gh}$$

or—

$$Q = C''\,\frac{\pi}{4}\,D^2\sqrt{2gh}$$

This equation in combination with a C''-r curve gives a direct solution for the size of orifice necessary for a given flow.

The pressures h_1, h_2, and h_3 at the three main sections of the orifice region are significant for the fact that they indicate the relation between the drop of pressure h_v equivalent to the increase in velocity and the pressure loss h_p caused by the sudden contraction and expansion of the flow. From the above equations, we can write—

$$C_p\sqrt{h_p} = C_v\sqrt{h_v}$$

from which

$$\text{Fraction of loss } Z = \frac{h_p}{h_v} = \left(\frac{C_v}{C_p}\right)^2 \quad \ldots\ldots [5]$$

and fraction of pressure restoration $= 1 - Z = 1 - \dfrac{h_p}{h_v} = 1 - \left(\dfrac{C_v}{C_p}\right)^2$.

The same applies to any of the experimental coefficients determined for the two sections corresponding to h_2 and h_3, respectively.

Computation of Results

The method adopted was to compute the rate of flow in pounds per minute for the calibrated impact nozzles used as a standard,

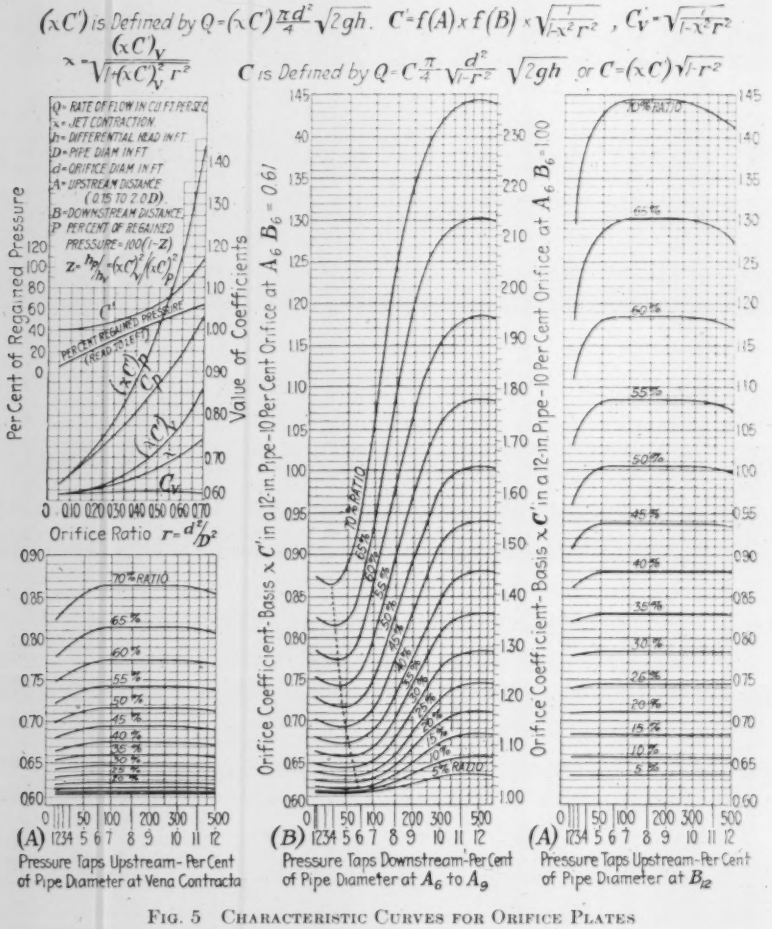
(xC') is Defined by Q=(xC')π/4 d²√2gh. C'=f(A)xf(B)x√(1/(1-x²r²)) , C'v=√(1/(1-x²r²))
x=(xC')v/√(1+(xC')²v r²)
C is Defined by Q=C π/4 d²/√(1-r²) √2gh or C=(xC')√(1-r²)
Q= RATE OF FLOW IN CU FT PER SEC.
x= JET CONTRACTION
h= DIFFERENTIAL HEAD IN FT.
D= PIPE DIAM IN FT
d= ORIFICE DIAM IN FT
A= UPSTREAM DISTANCE (0.15 TO 2.0 D)
B= DOWNSTREAM DISTANCE
P= PERCENT OF REGAINED PRESSURE = 100(1-Z)
Z= hp/hv = (xC')²v/(xC')²p
PERCENT REGAINED PRESSURE (READ TO LEFT)
Per Cent of Regained Pressure
Value of Coefficients
Orifice Ratio r=d²/D²
70% RATIO
65%
60%
55%
50%
45%
40%
35%
30%
25%
20%
15%
10%
5% RATIO
Orifice Coefficient-Basis xC' in a 12-in Pipe-10 Per Cent Orifice at A6 B6 = 0.61
Orifice Coefficient-Basis xC' in a 12-in Pipe-10 Per Cent Orifice at A6 B6=1.00
(A) 1 2 3 4 5 6 7 8 9 10 11 12
Pressure Taps Upstream-Per Cent of Pipe Diameter at Vena Contracta
(B) 1 2 3 4 5 6 7 8 9 10 11 12
Pressure Taps Downstream-Per Cent of Pipe Diameter at A6 to A9
(A) 1 2 3 4 5 6 7 8 9 10 11 12
Pressure Taps Upstream-Per Cent of Pipe Diameter at B12

FIG. 5 CHARACTERISTIC CURVES FOR ORIFICE PLATES

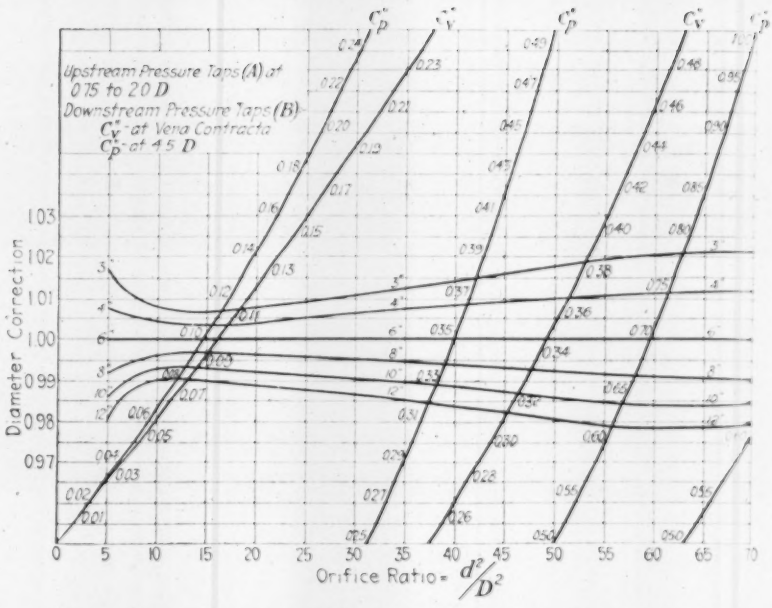
Upstream Pressure Taps (A) at 0.15 to 2.0 D
Downstream Pressure Taps (B)
C''v at Vena Contracta
C''p at 4.5 D
Diameter Correction
Orifice Ratio = d²/D²

FIG. 6 ORIFICE COEFFICIENT C'' FOR 6-IN. PIPE AND CORRECTION FACTORS FOR OTHER SIZES

and the rate in pounds per minute derived theoretically for the given orifice plate, assuming xC'' to be equal to unity. The actual value of the coefficient xC' for the given orifice is necessarily the ratio of the former to the latter. The method of procedure is demonstrated on the sample log sheets in the complete paper which contain the data of one A-run and one B-run on the 12-in. pipe.

The data of the final tests are recorded on 1625 log sheets filed in chronological order and cross-indexed under the various headings of impact tube, pipe size, and orifice ratio. A log sheet of the impact-tube tests contains a run on a given tube either varying the velocity head at constant setting or the setting at constant velocity. A log sheet of the orifice tests contains a run on a given-ratio orifice at constant velocity either varying the upstream A-taps with the downstream constant, or the downstream B-taps with the upstream constant. A complete test for a given orifice ratio comprises four velocity tests and from five to twelve log sheets for each velocity, part of them with A constant and B varying, and part with B constant and A varying. Each pipe size was tested for fourteen orifice ratios with the exception of the 2-in. pipe, on which the lower-ratio orifices were not completed at the writing of this paper.

Characteristic Curves of Orifice Plates

At the completion of a test for a number of orifice plates in a given size of pipe the values of the coefficient xC' were plotted in three sections on large sheets ruled in logarithmic coördinates. The first section represented the so-called A-curves plotted as a function of the upstream distances from the A-runs of the test with the downstream connection at the vena contracta. The second section represented the B-curves plotted as a function of the down-stream distances from the B-runs of the test. The third section consisted of A-curves plotted as a function of the upstream distances with the downstream connection at four and one-half diameters of the pipe or the point of complete restoration of pressure.

These curves, not given in the paper, represented in substance the form similar to the three main sets of the final curve, shown in Fig. 5 for the 10-in. pipe, except that in the original curves each orifice ratio was represented by a group of lines adjoining the test points of the several velocities for a given ratio. Also in those curves the actual orifice ratios were used, which differed somewhat from the equal divisions of the final curves in Fig. 5. With small exceptions the lines of each group did not

deviate much from each other, so that in each case a single line was drawn which represented the average value of the coefficient for the given ratio.

From these average lines the points of minimum and maximum were plotted on Fig. 4 as a function of the orifice ratio for the various sizes of pipe, the lower set for the coefficient $(xC')_v$ at the vena contracta, and the upper set for the coefficient $(xC')_p$ at four and one-half diameters from the orifice plate. After the points of the two sets on Fig. 4 were joined by smooth lines for the given sizes of pipes, the corrected values were obtained for the even ratios in multiples of five and the points transferred to the original curves and compared with the average lines of the nearest ratio. A new line was drawn parallel to the old one to pass through the corrected points for the even ratio. In this manner the effects of possible errors of observation were reduced, first, by comparison with the similar tests of the same ratio, second, by comparison with the similar tests of various ratios of the same size of pipe, and third, by comparison with the similar tests of the various sizes of pipes.

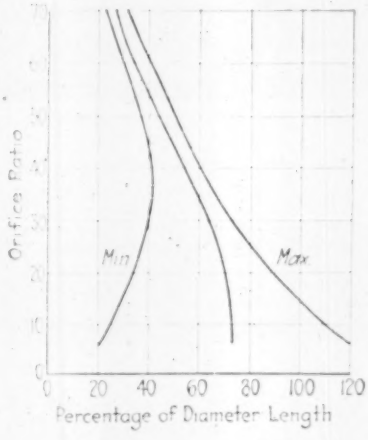

FIG. 7 SPACING OF TAPS AT VENA CONTRACTA

The final curves for the even ratios of the 6-in. pipe are shown in the three main sections of Fig. 5. These three sections give a generalization of the complete work for the given size of pipe. They point out forcibly the great importance that must be attached to the proper spacing of the orifice connections. In fact, they would seem to indicate that an excessive precision is necessary in determining these points, since a very small change in the tap distance along the steeper parts of the curves might cause a change of several per cent in the value of the coefficient.

To eliminate possibility of large errors in the practical application of the orifice, it is best, therefore, to select only those points for use at which a slight change in the position of the tap would not appreciably affect the coefficient. This condition is obviously fulfilled at the minimum and maximum points, since these points occur at the flat portion of the curve.

The A-curves given are restricted to as study of conditions at these two points. These two sets can be used in a similar manner to select the proper points at which to place the upstream pressure taps. Thus, since the flat parts of the curve occur between points A_6 and A_9, the upstream pressure taps should always be located between these points for the practical application of the orifice.

The curves in the upper left-hand section of Fig. 5 fulfil both of these conditions selected for good practice, that is, the upstream connections are always between 0.75 D and 2.00 D, and the downstream connections are at the vena contracta or at four and one-half diameters of the pipe. In this section are plotted as a function of the orifice ratio the values of xC', x, C', C and also the percentages of pressure restoration in the pipe. The values of these coefficients are given in Tables 1 to 6 for the various sizes of pipe.

The selection of the upstream and downstream distances to be used in general practice must not be taken as a limitation on the use of the orifice to these few points. With the proper care in spacing the pressure taps the coefficient corresponding to the exact distance can be easily and precisely obtained from the characteristic curve for the given pipe size.

TABLE 1 ORIFICE COEFFICIENTS FOR 12-IN. PIPE

Ratio $r = \frac{d^2}{D^2}$	$(xC')_v$	$(xC')_p$	x	C'	C_v	C_p	$1-Z$
5	0.603	0.624	0.603	1.000	0.603	0.624	0.067
10	0.610	0.650	0.609	1.002	0.607	0.647	0.119
15	0.614	0.676	0.612	1.003	0.607	0.668	0.174
20	0.620	0.703	0.615	1.008	0.608	0.689	0.223
25	0.627	0.736	0.619	1.013	0.608	0.714	0.274
30	0.637	0.774	0.626	1.018	0.608	0.739	0.326
35	0.649	0.818	0.633	1.025	0.608	0.767	0.371
40	0.663	0.867	0.641	1.034	0.608	0.795	0.416
45	0.679	0.923	0.649	1.046	0.606	0.824	0.459
50	0.700	0.987	0.661	1.059	0.606	0.855	0.497
55	0.725	1.063	0.674	1.076	0.605	0.887	0.535
60	0.756	1.157	0.689	1.097	0.605	0.926	0.573
65	0.795	1.273	0.706	1.126	0.605	0.968	0.610
70	0.846	1.413	0.728	1.162	0.604	1.010	0.641

TABLE 2 ORIFICE COEFFICIENTS FOR 10-IN. PIPE

Ratio $r = \frac{d^2}{D^2}$	$(xC')_v$	$(xC')_p$	x	C'	C_v	C_p	$1-Z$
5	0.606	0.627	0.606	1.000	0.606	0.627	0.066
10	0.611	0.652	0.610	1.002	0.608	0.649	0.122
15	0.615	0.678	0.612	1.005	0.608	0.670	0.177
20	0.621	0.705	0.616	1.008	0.609	0.691	0.224
25	0.630	0.738	0.622	1.013	0.611	0.715	0.271
30	0.640	0.777	0.629	1.018	0.611	0.742	0.321
35	0.651	0.821	0.634	1.026	0.610	0.769	0.371
40	0.665	0.870	0.642	1.035	0.610	0.797	0.416
45	0.683	0.926	0.653	1.046	0.610	0.827	0.456
50	0.704	0.992	0.664	1.060	0.610	0.859	0.496
55	0.730	1.069	0.677	1.074	0.609	0.893	0.534
60	0.761	1.165	0.692	1.099	0.604	0.932	0.573
65	0.800	1.281	0.710	1.127	0.608	0.974	0.610
70	0.851	1.420	0.728	1.163	0.608	1.014	0.641

TABLE 3 ORIFICE COEFFICIENTS FOR 8-IN. PIPE

Ratio $r = \frac{d^2}{D^2}$	$(xC')_v$	$(xC')_p$	x	C'	C_v	C_p	$1-Z$
5	0.610	0.631	0.610	1.000	0.610	0.631	0.065
10	0.613	0.654	0.611	1.003	0.610	0.651	0.120
15	0.618	0.680	0.615	1.005	0.611	0.672	0.175
20	0.624	0.708	0.619	1.008	0.612	0.694	0.223
25	0.632	0.741	0.624	1.013	0.613	0.718	0.272
30	0.643	0.780	0.631	1.019	0.614	0.744	0.320
35	0.655	0.825	0.638	1.027	0.614	0.773	0.369
40	0.670	0.874	0.646	1.035	0.614	0.801	0.412
45	0.688	0.931	0.657	1.047	0.614	0.831	0.454
50	0.710	0.997	0.669	1.061	0.614	0.863	0.493
55	0.736	1.076	0.682	1.079	0.614	0.898	0.532
60	0.767	1.173	0.697	1.100	0.614	0.939	0.572
65	0.806	1.290	0.714	1.129	0.613	0.982	0.609
70	0.856	1.430	0.734	1.166	0.612	1.021	0.641

In an earlier paragraph the orifice coefficient C'' was mentioned as affecting the simplest solution of orifice problems since it relates directly to the known section of the pipe D^2. Accordingly, Fig. 6 was prepared in a convenient form for ordinary use, giving values of C''_v and C''_p as a function of the ratio. To eliminate the necessity of repeating the curves for each size, only those for the 6-in. pipe were prepared, and additional lines were drawn to scale giving correction factors to be used in obtaining the coefficient for the other pipe sizes.

Fig. 7 shows the spacing of pressure taps at the vena contracta in percentage of the diameter length corresponding to the given orifice ratio. The center line is a duplicate of the one passing through the minimum points of the characteristic B-curves in Fig. 5. The two outside curves, marked "min." and "max.," show the limits to which the tap may be shifted without varying the coefficients more than 0.25 per cent either way. The actual spacing

TABLE 4 ORIFICE COEFFICIENTS FOR 6-IN. PIPE

Ratio $r = \frac{d^2}{D^2}$	$(xC')_v$	$(xC')_p$	x	C'	C_v	C_p	$1-Z$
5	0.635	0.636	0.615	1.000	0.615	0.636	0.065
10	0.645	0.657	0.614	1.002	0.612	0.654	0.123
15	0.620	0.683	0.618	1.003	0.614	0.675	0.175
20	0.626	0.711	0.621	1.008	0.614	0.698	0.225
25	0.635	0.745	0.627	1.013	0.615	0.722	0.273
30	0.646	0.784	0.634	1.020	0.616	0.748	0.320
35	0.659	0.829	0.642	1.027	0.618	0.777	0.368
40	0.674	0.880	0.650	1.037	0.618	0.807	0.413
45	0.693	0.938	0.662	1.047	0.619	0.838	0.455
50	0.716	1.004	0.674	1.062	0.620	0.870	0.487
55	0.742	1.084	0.687	1.081	0.619	0.905	0.511
60	0.774	1.183	0.702	1.103	0.619	0.947	0.572
65	0.813	1.301	0.719	1.131	0.618	0.990	0.609
70	0.864	1.444	0.739	1.170	0.617	1.031	0.642

TABLE 5 ORIFICE COEFFICIENTS FOR 4-IN. PIPE

Ratio $r = \frac{d^2}{D^2}$	$(xC')_v$	$(xC')_p$	x	C'	C_v	C_p	$1-Z$
5	0.619	0.642	0.619	1.000	0.619	0.642	0.070
10	0.617	0.661	0.616	1.002	0.614	0.658	0.130
15	0.622	0.686	0.620	1.003	0.615	0.678	0.177
20	0.628	0.710	0.624	1.007	0.616	0.702	0.231
25	0.638	0.750	0.630	1.013	0.618	0.727	0.276
30	0.650	0.790	0.638	1.019	0.620	0.754	0.323
35	0.662	0.835	0.645	1.027	0.621	0.782	0.371
40	0.680	0.886	0.656	1.037	0.623	0.812	0.411
45	0.700	0.946	0.668	1.048	0.625	0.845	0.452
50	0.723	1.014	0.680	1.063	0.626	0.878	0.491
55	0.750	1.096	0.693	1.083	0.626	0.915	0.531
60	0.782	1.197	0.708	1.105	0.626	0.958	0.572
65	0.820	1.318	0.723	1.135	0.624	1.002	0.613
70	0.873	1.464	0.745	1.172	0.624	1.045	0.644

TABLE 6 ORIFICE COEFFICIENTS FOR 3-IN. PIPE

Ratio $r = \frac{d^2}{D^2}$	$(xC')_v$	$(xC')_p$	x	C'	C_v	C_p	$1-Z$
5	0.624	0.649	0.624	1.000	0.624	0.649	0.074
10	0.619	0.663	0.618	1.002	0.616	0.660	0.125
15	0.623	0.688	0.621	1.003	0.616	0.680	0.179
20	0.631	0.718	0.626	1.008	0.619	0.704	0.227
25	0.641	0.754	0.633	1.013	0.621	0.731	0.277
30	0.653	0.795	0.641	1.018	0.623	0.759	0.325
35	0.668	0.841	0.651	1.026	0.626	0.789	0.369
40	0.684	0.893	0.660	1.036	0.627	0.818	0.413
45	0.705	0.953	0.672	1.049	0.629	0.853	0.453
50	0.728	1.022	0.684	1.064	0.630	0.885	0.492
55	0.756	1.106	0.698	1.083	0.631	0.923	0.532
60	0.788	1.210	0.713	1.106	0.630	0.968	0.577
65	0.827	1.331	0.728	1.136	0.629	1.012	0.615
70	0.880	1.480	0.749	1.175	0.629	1.057	0.626

should be made as nearly as possible to that given by the center curve, since it is drawn to indicate the exact position of the vena contracta.

Conclusion

The scope of this paper will not permit of going into the particular details of each individual test. Its main object is to present the results obtained in the research laboratory in such a form that they can be applied conveniently.

A few remarks may be in order about the most salient points brought out by this investigation.

The orifice plate used as a measuring device for the flow of fluids in pipes has a relative accuracy well within the limit of 2 per cent. If reasonable care is applied in the selection of the location, the proper spacing of the pressure taps, and the proper centering of the orifice between the flanges in the pipe, the possible deviation may be reduced to less than 1 per cent. The maximum variation from the average in any single test seldom exceeded 1 per cent when the differential pressure was above 1 in. of water.

The loss of head through the entire region affected by the orifice, which is the differential to the point of complete restoration, is an accurate function of the velocity squared—the same as that of the drop of pressure to the vena contracta. This means that the coefficient C_p is just as reliable as the coefficient C. In cases where the pressure difference has an appreciable value it is even better to use the point of restoration, as the curve is much flatter at that point, in the case of large-ratio orifices, and a deviation from the proper section will not result in any appreciable error.

The coefficient of discharge C_v is shown to be very nearly constant for orifices of all ratios. This would mean that the orifice can be treated as a venturi, using the same value of C_v and correcting for initial velocity of approach the same as is done in the venturi tube.

The jet issuing from the orifice does not contract to the same extent in the smaller sizes of pipes. This is probably due to the fact that the portion of the flow which is restricted by the orifice has a proportionately lower velocity due to the increased skin friction in smaller sizes of pipes.

The variation of velocity pressure from 100 to 300 per cent does not affect the value of the coefficient. This seems to indicate that the name "frictionless orifice" is not misleading. For this reason it is best to use very thin material for the orifice plate to eliminate the friction at the sides of the opening. If the material has to be heavier, it is advisable to bevel the *downstream* side of the opening.

The regained head increases very rapidly with the increase of orifice ratio, making the larger-ratio orifice more applicable to cases where the loss of pressure is an important item.

Reference is made to the fact that the characteristic curves given in this paper are based upon the assumption that the coefficient of discharge for a 10 per cent orifice in a 12-in. pipe is equal to 0.61. This assumption, however, is borne out by the results of previous experiments by many authorities and can be further substantiated by additional volumetric tests at this point. The experiments, as demonstrated in this work, have shown that the orifice plate is relatively accurate for measuring the flow of fluids for the varying sizes of pipes and the various ratios of orifices at the proper spacing of the pressure taps. The characteristics curves given in the paper have a complementary scale with the basic value of 0.61 as unity, so that if further experiments should prove that the 10 per cent orifice in a 12-in. pipe has a value somewhat different from the one given, these curves can be applied in the same manner to the new value of the standard.

Discussion[1]

R. J. S. Pigott[2] wrote that the paper was especially interesting in that the values obtained and the characteristics of the stream, when taken in conjunction with the dimensional analysis given in the Fluid Meters Report, afforded a means of coördination of practically all of the experimental work on disk orifices. Heretofore these experiments had been thought to show considerable variation from each other, but when allowance was made for the difference of location in upstream and downstream taps, the ratio of orifice sizes, pipe sizes, and the location of vena contracta, it was found that nearly all the experiments gave coefficients substantially in agreement. Allowing for the difference of view of the various experimenters, it was very encouraging that this should

[1] These extracts from the discussion deal more particularly with those portions of the paper appearing in the preceding abridgment. The table and figure numbers are those used in the abridgment.

[2] Mechanical Engineer, Stevens & Wood, New York, N. Y. Mem. A.S.M.E.

be the case, and it was curious that the mathematical analysis of this flow prepared by Dr. Buckingham of the Bureau of Standards for the report should have predicted the characteristics of the orifice as found by Mr. Spitzglass, each working entirely without knowledge of the other's results. It was unfortunate that nearly every experimenter on both venturi tubes and the disk orifices should have used a different system of plotting and comparison; but possibly by trying all the different ways the best method would be adopted by the public who had to use them.

J. W. Hogg,[2] in a written discussion, said that it would be well to know whether the coefficient of the basic orifice, as well as the results derived from its use as a means of calibration, were applicable to steam and water, and possibly to other fluids heavier or lighter than water but possessing a different viscosity.

Fig. 7 showed that a good location for the low-pressure fitting was one-half of a pipe diameter behind the plate for ratios up to 50 per cent, therefore if the flow could be measured between this range without excessive differential head, a distance of one-half pipe diameter behind the orifice might be taken as a fixed location for the low-pressure connection.

It would be noted on Fig. 4 that the coefficient of discharge for a given ratio of areas decreased as the pipe size increased. The author stated in one of his concluding paragraphs that the jet issuing from the orifice did not contract to the same extent in the smaller size of pipe as it did in the larger, and further that this was probably due to the fact that the portion of the flow which was restricted by the orifice had proportionally lower velocity due to the increased skin friction in the small pipes. It then appeared that the ratio of the perimeter of the pipe to the area of the pipe or some other similar function could be incorporated in a equation to be used in figuring the coefficients for sizes of pipe which were entirely too large to be erected in a laboratory for experimental purposes. After this equation was determined the coefficient of discharge for these large pipes, such as 18-, 24-, and 30-in., could be easily interpolated.

It would also be noted in Fig. 4 that the two sets of coefficients depending upon whether the vena contracta or the point of restoration were used as the location of the low-pressure fitting were widely different in value, and the set of coefficients at the vena contracta might be termed low coefficients, while the set at the point of restoration might be termed high coefficients. It appeared from all the data taken in this test that sufficient was on hand to determine a set of coefficients with intermediate values with respect to the other two sets, and this set could be obtained by locating the high-pressure fitting at the point of restoration and the low-pressure fitting at the vena contracta.

A. F. Spitzglass[3] wrote that it seemed best for practical work in calculating orifices that separate curves be used for each size of pipe. The values for determining these curves could be obtained from Tables 1 to 6 by multiplying the values given in the first column for $(\alpha C')_2$ by the orifice ratio r.

Since the completion of the tests the objection had been raised that the Ellison gages could not be relied on to give results within the limits of accuracy necessary for laboratory work, unless calibrated individually against some absolute standard. Lest this cause reflection to be cast upon the value of the data given, it seemed necessary to explain the methods adopted to overcome this difficulty.

Each test was essentially a comparison of two similar functions of the pressure head at two different points in the stream. Neglecting the corrections applied, the coefficient varied as the square root of the ratio of the orifice differential to the head on the impact nozzle. Thus, only a relative accuracy between the two devices used for determining the pressures was necessary to give the required precision. With this in mind, tests were made on a large number of gages, checking them against each other over the complete range of their scales. Of these, three were finally selected that gave practically identical readings along the entire scale. One of these was used for obtaining the orifice differential and the other two for obtaining the head on the impact nozzle. To retain this precision it was necessary, therefore, to choose a nozzle of such a cross-section that the two gages would read on the same part of the scale. Furthermore, in averaging the results of any of the tests, most weight was given to those runs in which the two pressures were nearly identical.

George S. Hendrickson[5] wrote that the calibration curves for the impact nozzles showed that the coefficient changed when the velocity changed, due to the friction. As he understood it, the coefficient of the venturi tube was given as a constant irrespective of the velocity, and the conclusion he drew was that both could not be correct. He would ask whether coefficients of the venturi tube had shown a variation at different velocities.

All the tests had been made for a given pipe size in the same pipe by varying the orifice ratio. In commercial pipe it was safe to assume that the inside surface of different pipes would not have the same characteristics. One piece might be very smooth and another quite rough. He believed that this might affect the orifice coefficient, especially on the larger ratios and higher velocities.

C. A. Dawley[6] wrote that the arrangement of flow nozzles on manifolds as shown in Fig. 3, was unfortunate from the fact that the air flow had to make three right-angle turns within a short distance, thereby creating violent disturbances or eddies in the flow stream. This piping would naturally produce swirling or helical flow in the vertical pipes leading to the flow nozzles, and would certainly give a higher velocity on one half of the opening of the nozzle than on the other half. The net result of both of these irregularities would be to give a low, and perhaps a variable, coefficient for the nozzles. The fact that the coefficients found did not increase systematically with the diameter and that they were uncertain or variable in some instances, supported the belief that they were influenced by the conditions of installation. It would be of value if the author would explore, with a search tube, the whole area of the nozzle outlets as installed, finding the velocity across two diameters at different radii compared with that at the center, and then that the 3- and 4-in. nozzles should be installed in turn directly at the end of the 12-in. pipe in which the disk orifice was located and a further determination made on the relative coefficients.

The most important point settled by the paper was the location of the vena contracta and the point of maximum restoration of pressure beyond the disk orifice. For the range of heads covered by the author's tests, these results should stand regardless of any minor inaccuracy in the coefficients of the impact flow nozzles as found.

E. G. Bailey[7] wrote that it was unfortunate that the author had deemed it best to present the data in such form that they could not well be correlated or compared with other data previously presented to the Society on a similar subject. It was also very unfortunate that he did not have a standard or basic measurement upon which to start the comparison. The flow nozzles were calibrated on an assumed coefficient of one orifice, then the orifices were recalibrated on the basis of the flow nozzles. The same flow nozzle could not be used for all the different sizes of pipe, so that the final results were rather far from a definite absolute basis. Mr. Bailey believed the results as a whole gave coefficients too high; also that the paper showed more difference between the coefficients of different sizes of pipe than actually existed. While most of the data might be within 2 or 3 per cent of correct absolute value, he thought in the present state of the art greater accuracy was expected of the meter manufacturer. It was to be hoped that some subsequent tests could be made to substantiate or modify these absolute values as mentioned in the last sentence of the paper.

It would be interesting to know why Mr. Spitzglass had limited his test to a 70 per cent ratio orifice which was equivalent to 83.70 diameter ratio.

The use of circular concentric orifices gave no latitude as to the location of the vena contracta. This was rather annoying when high hub flanges were encountered; also when a pipe was tapped for an orifice of one capacity and later an orifice of a different capacity was to be installed. This might require retapping the connections at a comparatively short distance away, so that it could not

[3] Republic Flow Meters Co., Philadelphia, Pa. Jun. A.S.M.E.
[4] Engineer, Republic Flow Meters Co., Chicago, Ill.
[5] Sales Engineer, Republic Flow Meters Co., Chicago, Ill. Assoc-Mem. A.S.M.E.
[6] Consulting Engineer, N. J. Meter Co., Plainfield, N. J. Mem. A.S.M.E.
[7] Bailey Meter Co., Cleveland, Ohio. Mem. A.S.M.E.

be accomplished without going to another position on the circumference of the pipe. He had found it very advantageous in such conditions to use eccentric and segmental orifices.

John L. Hodgson[3] wrote that the author had repeated work which he had briefly summarized in Fig. 18 of his paper on the Commercial Metering of Air, Gas and Steam, read before the Institute of Civil Engineers in April, 1917.

Commenting on Mr. Spitzglass's paper, he would say that the contour of the impact nozzles used in the tests was unsuitable for low-pressure work, as the effect of viscosity, which was most marked at low flows, altered the shape of the stream lines, and hence the distribution of velocity across the section. A nozzle contour which was suitable for Mr. De Baufre's purpose was entirely unsuitable for that of Mr. Spitzglass, where it was essential to work at values of $p_2 \; p_1$ which were very nearly unity.

The proposal to use pressure holes further downstream rather than the vena contracta for flow-measurement purposes was, according to Mr. Hodgson's tests, suitable only for the most approximate measurements (unless the orifice had been calibrated in its own pipe line) as variations in the roughness and in the case of large orifice ratios—the diameter of the pipe caused very considerable variations in the flow coefficient.

It was unsatisfactory to use circular orifices for area ratios greater than 50 per cent, as small errors in centering or in the diameter of the pipe upstream or downstream of the orifice caused considerable errors in the measurement.

For many reasons the most reliable position for the pressure holes was in the plane of the orifice as he had shown in his paper above referred to. It was a matter for regret that Mr. Spitzglass had determined no pressures at these particular points.

Author's Closure

The author, in closing the discussion, said that in regard to Mr. Hogg's question as to whether the coefficient 0.61 for the 10 per cent orifice in a 12-in. pipe was applicable for water and steam as well as for air, the dimensional analysis given in the Fluid Meter Report showed that the values of the coefficient depended on the kinematic viscosity of the fluid, but from all experimental data available water, steam and the common gases showed no difference in the coefficient of the orifice.

As to adopting a distance of one-half diameter for the low-pressure connection of the orifice, he would say that this method had been used by many experimenters, but there was no advantage in adopting it for general practice. In a high-ratio orifice it was very important to place the connection at the proper point and it was best to adhere to this practice. If at any time the orifice was to be changed it would not be necessary to change the connection, as the difference in the factor could be easily obtained from the curves in the paper.

Mr. Hogg had asked whether an equation could be derived to determine the effect of pipe size upon the coefficient of the orifice from the relation of the mean hydraulic radius as pertaining to the friction drop of pressure. The dimensional equation referred to was supposed to correlate the results of tests so that the data of one size of pipe would apply to other sizes by following the law of dynamical similarity in the construction of the orifices.

Mr. Hogg had suggested that an intermediate coefficient be determined by locating the high-pressure tap at the point of restoration and the low-pressure tap at the vena contracta. This was a very good suggestion and to take care of it a modification of Fig. 6 had been prepared for inclusion in Transactions.

The suggestions made by A. F. Spitzglass were a slight addition to the work he had done in preparing the results of the paper.

In reply to Mr. Hendrickson's inquiry, he would state that the coefficient of venturi tube did vary with the velocity of the flow similar to the variation shown on the impact-tube curves. This variation was due to the effect of friction on the approach part of the venturi tube or nozzle. Since the coefficient of friction was generally increased at low velocity, there was a corresponding decrease in the coefficient of discharge, because the additional friction drop increased the relative differential pressure.

As to whether the roughness of the pipe affected the coefficient, he would say that from his experience the nature of the surface was not noticeable except in very high-ratio orifices. For that reason he preferred not to use orifices over the 70 per cent ratio of squares, in which the effect of the surface became noticeable.

If Mr. Dawley would examine Fig. 3 carefully he would see that the first two turns were really long-radius bends and of a size considerably larger than the approach of the flow nozzle. The air flow through any of the pipes lost practically all its velocity when entering the second manifold, which was 14 in. in diameter. The entrance to the third manifold was a long-radius bend of the same 14-in. size. On the top of this manifold each riser was over 6 ft. long and the diameter of the riser was about half the diameter of the manifold and double the diameter of the flow nozzle. With this construction of approach there should be no disturbance or eddies in the flow stream.

Mr. Dawley's suggestion to explore the whole area of the nozzle was carried out during the test. It was found that in case of the 4-in. nozzle the impact pressure did not vary at all until the impact tube was placed $\frac{1}{4}$ in. from the circumference of the nozzle. At that point it varied about 1 per cent of the total impact, and when the impact tube was placed so that its edge was in line with the edge of the nozzle, the reduction of the impact pressure was only 3 per cent of the total. This variation was the same in either direction of the nozzle, whether in line or across the turn of the flow at the bottom of the riser.

Mr. Bailey had objected to the method used in the paper to plot the results of the test on the basis of diameter square instead of diameter ratio, which he said was the basis used in Mr. Judd's paper and in others published on the subject. Referring to Figs. 18 and 20 of Mr. Judd's paper, it would be noted that the coefficient of discharge and the factor of correction for velocity of approach were plotted on the basis of the ratio of orifice area to pipe area, and not on the ratio of orifice diameter to pipe diameter. If Mr. Judd chose to call a $2\frac{1}{2}$-in. orifice in a 5-in. pipe a 50 per cent orifice, while the results obtained with this orifice were plotted on the 25 per cent line in his main curves, it did not entail any difficulty to compare the author's results with his when he chose to call it a 25 per cent orifice, inasmuch as it really amounted to that figure in the actual comparison of results.

With reference to higher-ratio orifices, the tests had not been limited to 70 per cent, but the results obtained for higher ratios had indicated that extreme accuracy was required in centering the orifice plate and in measuring the pipe diameter. Higher ratios were being investigated at present and the results would be reported later.

Mr. Hodgson's objection to the contour of the impact nozzle used did not apply to this case, because in the author's tests the nozzle was only a means of conveying a stream of fluid and measuring the velocity pressure with an impact tube faced against the stream. The preliminary tests referred to in the paper were made with a nozzle tube, similar to the one shown in Fig. 1 of the paper presented by Sanford A. Moss to the Society in December, 1916. In the final tests the design adopted by Mr. De Baufre was used to see whether the change in design made any difference. In both cases the same velocity pressure was obtained throughout the full area of the nozzle. There was only a change of 3 per cent in the velocity head, which would mean approximately 1.5 per cent velocity at the very circumference of the jet. This proved conclusively that the form of rounding the nozzle was immaterial when used in connection with an impact tube for obtaining the velocity pressure. The use of pressure taps at the point of restoration was recommended because the curve of the coefficient was much flatter at that point in the case of the high-ratio orifices.

Mr. Hodgson did not recommend the use of orifices of over 50 per cent ratio, for the reason that small errors in centering or in the diameter of the pipe would cause considerable error in the measurement. With the method of centering shown in the paper and the correct measurement of the diameter of the pipe, the results appeared to be equally reliable up to an orifice ratio of 70 per cent. As earlier stated, higher ratios were being investigated at present and the results would be reported later.

Mr. Hodgson regretted that readings were not taken of the pressures in the plane of the orifice. This was not necessary, as by extending the numerous points in the first diameter length toward

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(Continued on page 399)

Steel-Car Construction at the Angus Shops of the Canadian Pacific Railway, Montreal

By H. R. NAYLOR,[1] MONTREAL, CANADA

In 1909 the Canadian Pacific Railway, to meet the increasing severity of modern traffic requirements, originated a box car having its entire frame built of steel. The production of such equipment in quantity necessitated the erection of an additional shop for the fabrication of the steelwork, and the structure built embodied in its arrangement many novel features for the rapid handling of material to and from the machines and also during the various stages of assembly.

The present paper describes this shop very completely, giving particulars regarding its layout, crane facilities, machine equipment, etc. The various machining operations and the jig method of car assembly, first put into practice at the Angus shops, are presented in detail, and the methods used in the final erection and finishing of cars are dealt with at some length.

IN REVIEWING the improvements that have been effected in railway engineering in recent years, reference is usually made to the heavier and more powerful locomotives employed, grade elimination, heavier rails, improved train control, and terminal facilities; but while great advances have been made in all these directions, it is a question whether the relative advance in any one of them has equaled that in car construction.

The locomotive of higher capacity has been built without material change in the shops or their equipment, grades are removed today in practically the same manner as when the lines were originally built, and the same remarks hold good in regard to rails, train control, and terminal facilities, but in car construction the situation is substantially different. To particularize, a comparison of the modern 60-ton steel-frame box car with the 30-ton wood-frame box car commonly built fifteen years ago brings out two points: the complete change in design, and the effect this change in design must have had on the car shops. It is obvious that the facilities for building the wood-frame car would be quite inadequate for the steel car and must have created new problems with which the car builder had to contend; and it is the author's intention to deal with this phase of steel-car construction, especially as the Canadian Pacific Railway was responsible for many of the important developments.

Development of the Steel-Frame Box Car

The gradual increase in locomotive capacity, making possible the hauling of longer and heavier trains, subjected the wooden cars to severe service conditions, which were in turn met by steel underframes and other steel reinforcements; and at each stage of advancement wood framing was gradually replaced by steel, until in 1909 the Canadian Pacific Railway originated a box car having the entire frame built of steel.

Within a period of six years (1909–1914) this road added 30,841 steel-frame box cars to its equipment and others soon adopted the same design, in some cases with slight modifications. After ten years of extensive service these cars had evidently proved their utility, for the United States Railroad Administration in one order alone included no less than 50,000 of this type.

The Angus shops were already well equipped for building passenger and freight cars on an extensive scale, and the output of wood-frame box cars had reached as high as 40 cars per day. This remarkable organization, however, was rendered obsolete to a large extent when the Canadian Pacific Railway introduced the steel-frame box car to meet the increasing severity of modern traffic requirements, necessitating the erection of an additional shop. This shop was designed for building the steelwork of both passenger and freight equipment, and embodied in its arrangement many novel features for the rapid handling of material to and from the machines, and also during the various stages of assembly. At the time of its erection it probably represented the best practice on this continent, being a combination of the good features observed in other shops with the original ideas developed at the time the layout was being planned.

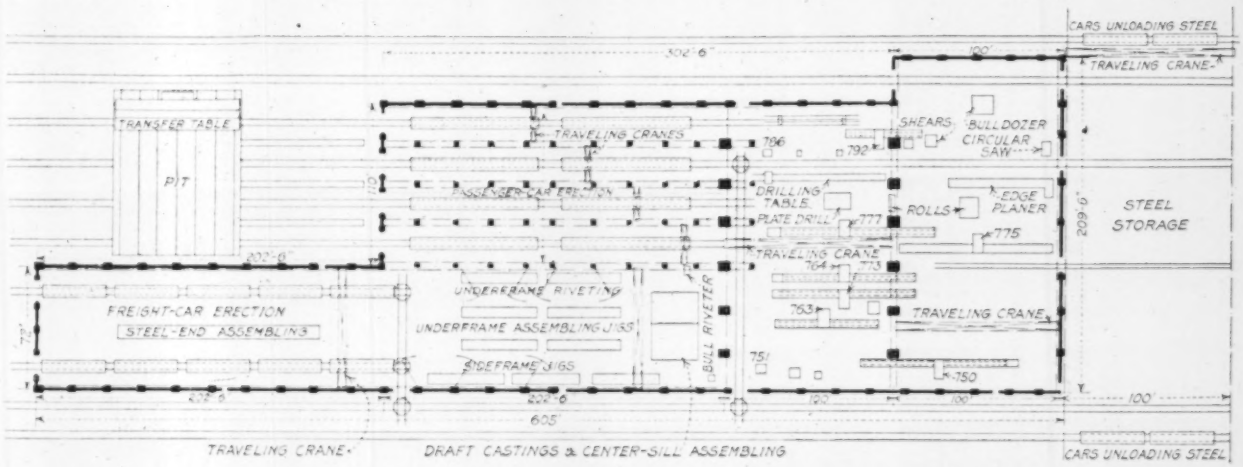

FIG. 1 PLAN OF STEEL-CAR SHOP OF THE CANADIAN PACIFIC RAILWAY CO. AT ANGUS SHOPS, MONTREAL, CANADA

The Steel-Car Shop and Its Equipment

The new shop, which is shown in plan in Fig. 1, was located adjoining the wood-freight-car shop, facing a midway upon either side of which were also located the supplementary shops, the midway being served with overhead traveling cranes. It is a steel-frame structure, with steel columns carried on concrete piers, the lower foundation walls being of concrete, 24 in. thick to the ground level and 20 in. thick to a height of $2^3/_4$ ft., above which the walls are of red brick and 16 in. thick. The sash frames are of steel, the total sash area being approximately 40 per cent of the total wall space. The roof is carried on steel trusses with ample skylight area. The floors are of 4-in. concrete with a top surface of $^5/_8$-in. mastic.

There are three main divisions to the shop. The front one facing the midway and occupying the entire front is the machine section consisting of two 100-ft. bays running parallel to the midway, the one adjoining the midway being $209^1/_2$ ft. long, while the inner bay is 182 ft. long. Each bay is served by a 10-ton elec-

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trically operated crane of the open-latticework type having a span of 96 1/4 ft., and a height to base of rail of 28 1/2 ft.

The freight-car erecting section is situated in the rear of the machine section, is 72 ft. wide and 405 ft. long, and was originally equipped with one 10-ton traveling crane having a span of 67 1/2 ft., and a height to base of rail of 27 ft. An additional crane of similar capacity has since been installed in this section.

Situated also to the rear of the machine shop is the passenger-car erecting section, consisting of four bays having a total width of 110 ft. These four bays with the 72-ft. freight-car bay complete the full width of the back of the machine shop. Each bay of the passenger-car section is provided with a separate 2-ton traveling crane having a span of 24 ft. 10 in. and a height to base of crane rail of 21 ft.

Along the entire front of the shop, between it and the midway, there is ample provision for storing material. This storage yard is 100 ft. wide and is served by a 10-ton crane whose span and height are identical with those in the machine section in anticipation of future shop extension.

Through the freight-car erecting shop, entering from the rear end, are two standard-gage tracks 18 ft. center to center which extend the full length but do not enter the machine shop. Outside the shop and parallel to the south wall a standard-gage track connects with a track on the midway through turntables. This track is used for delivering the car trucks from the truck shop to the final-assembly tracks.

Through each of the passenger-car erecting bays there is a standard gage track leading in from the rear of the shop, also a transfer table for moving the cars during the various stages of completion. Through the center of the material storage yard there is a standard-gage track connecting by turntables with three tracks running into the machine shop.

Crane Facilities. The crane facilities are unique in that the whole area of the shop is traversed by electrically operated traveling cranes so arranged that it is possible to install an unusual number and yet maintain for each crane complete freedom of operation at all times. In this instance the crane arrangement was the deciding factor in the shop layout. It was decided that the machine section of the shop should be independent of the erecting sections in so far as crane service was concerned, and for this reason the crane runways in this section were installed in a direction transverse to those in the erecting shop. This arrangement made it possible to equip the two machine bays with separate cranes, each having a wide range of action with no interference.

The machine layout is arranged with the view of relieving the overhead cranes to the greatest possible extent. This applies particularly to the handling of the larger members, such as center and side sills which are required to pass over two punching machines situated in the different bays. As the first operation is completed the sills are transferred to the second machine by special devices independently of the overhead cranes. On completion of the machining operations the sills are then skidded over to the assembling trestles in the erecting shop without assistance from the overhead cranes.

The two cranes in the freight-car erecting shop, operating on the same runway, are entirely free from machine-shop handling, and as the first one is assigned to the preliminary assembly positions and the second to the final assembly positions, there is no overlapping or interference. The crane facilities in the machine and freight-car erecting shops will be better appreciated if one will endeavor to imagine four cranes on a single runway attempting to handle an equivalent amount of work.

The Machine Equipment. The machine shop is equipped with the following machinery: Four automatic spacing punches, five coping punches, five high-speed punches, two horizontal punches, one 7-ft. 6-in. gate shear, one angle shear, one 36-ft. plate-edge planer, one 30-in. circular saw, one 30-in. metal band saw, one 7-ft. plate roll, one 10-ft. brake, one bulldozer, two special plate-drilling machines, and miscellaneous drill presses, all driven by independent motors.

The arrangement of the machines is such that the material after each operation moves forward in the direction of the erecting shops, backward movement being carefully avoided, thereby reducing material handling to a minimum.

The high-speed punches are belt-driven direct from motor to flywheel, gears being dispensed with. Clutches are of the 6-point type. The heads are equipped with two punches which are controlled by gag levers. These machines are well adapted for punching the smaller plates for which metal templets are made up and into which holes are drilled; by inserting a pin or gage in each successive hole and butting the plate against the pin, the desired spacing is obtained. In certain classes of work the operator can move the material fast enough to catch every hole with the punch running at the rate of 60 strokes per minute.

An unusual plan was followed as regards the installation of machines for heavy punching. The usual practice had been to install a small number of high-capacity machines for the punching and slotting of the sills, side plates and similar members, necessitating frequent changing of dies and templets, with further limitations in the event of breakdowns. It was therefore decided to overcome these handicaps by installing four automatic spacing punches of moderate capacity to obviate the expense and delay of die changing and double handling, and as the five additional coping punches are duplicates of those used in the automatic spacing tables, replacement can be made with but short delay should they become disabled.

Machining Operations on the Car Steelwork

The machines are served by narrow-gage service tracks running from the material storage yard, special care being taken to unload the material close to the track by which it will enter the shop. The progress of material through the machine shop is as follows: Center sills and side-sill channels are loaded by overhead crane and brought into the shop on service lorries and deposited on trestles opposite the traveler at rear of center- and side-sill web spacing punch No. 775. Two air-operated traversing jacks lift the sills in pairs and place them on the traveler rollers ready to pass through the machine. On the far side of this punch, as shown in Fig. 2, is an elevated runway carrying the traveler head which grips the sills with its projecting jaws and automatically spaces the punching. Along the traveler runway steel templets with projecting pins engage a trip lever suspended on the head of the traveler, close the electric circuit, arrest the travel of the head, and close the circuit of the punch control; the punch then completes the operation. After passing through this machine the sills are released from the jaws of the traveler, lifted by jib cranes as shown in Fig. 2, and deposited back to back on the rollers of sill-flange-spacing punch No. 777, which are placed directly opposite the delivery end of the web punch. On completion of the first operation the sills are disengaged from the head clamp and pushed back over the rollers to the starting point, where they are again turned over by a special device attached to the jib cranes and passed through the machine for the second operation on the opposite flanges. The sills are then lifted by the traveling crane of the inner section of the machine shop and placed on the rollers of coping punch No. 763 directly opposite, where draft-key and lever slots are punched, completing the operations on the sills.

The center-sill and body-bolster cover plates and similar plates are punched on spacing punch No. 750. The side plates are punched on automatic spacing punch No. 764 in a similar manner to the sills, passing through for the first and second operations in pairs.

In all of these operations the passage through the machines is rapid and the accuracy of the spacing mechanism is such that the punching error is slight and far less than it would be were each hole marked off and punched independently.

There are certain parts which cannot be handled satisfactorily on the spacing punches, yet the punching must be equally as accurate or otherwise much of the benefit obtained from the spacing punches is lost when the parts are assembled. The machining of the ends of the side posts and braces is an example of this kind. In this case special combination dies are used to shear the ends to shape and punch the group of holes in one operation.

The bolster cover plates and diaphragms are machined in a similar manner, the cover plates being passed over the spacing punch and the diaphragm flanges punched on one of the coping punches equipped with special dies for punching the flange holes in one operation. During these operations the machine is relieved

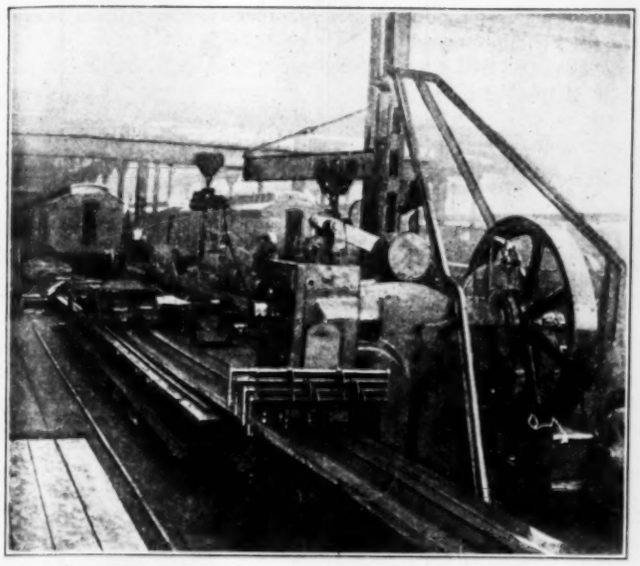

FIG. 2 CENTER- AND SIDE-SILL WEB SPACING PUNCH

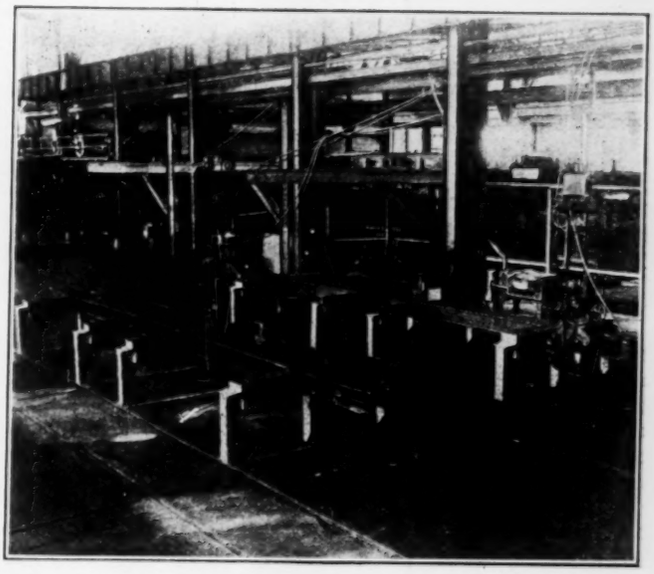

FIG. 3 JIGS USED IN ASSEMBLING UNDERFRAMES

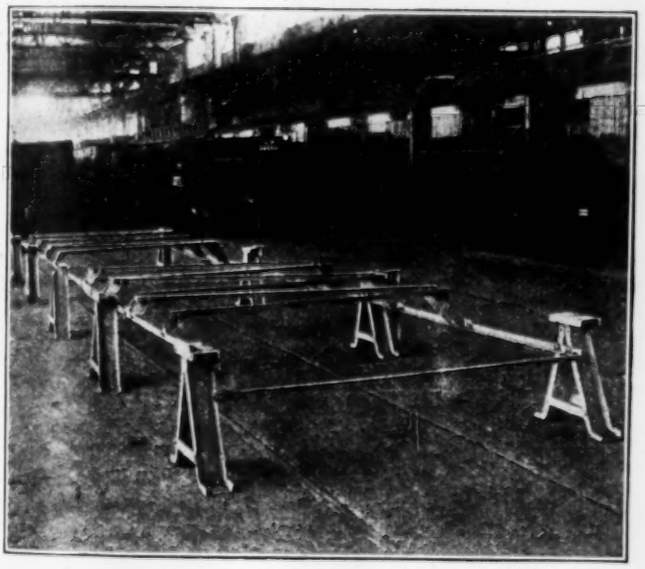

FIG. 4 JIG USED IN ASSEMBLING SIDE FRAMES

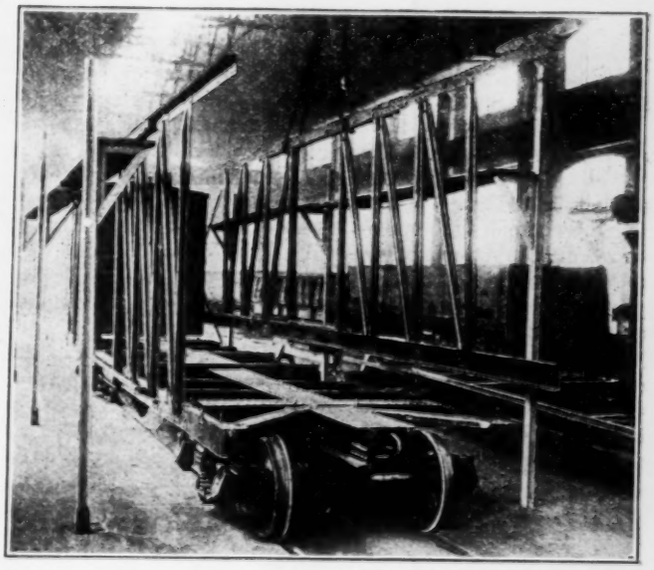

FIG. 5 PLACING THE SIDE FRAMES IN POSITION

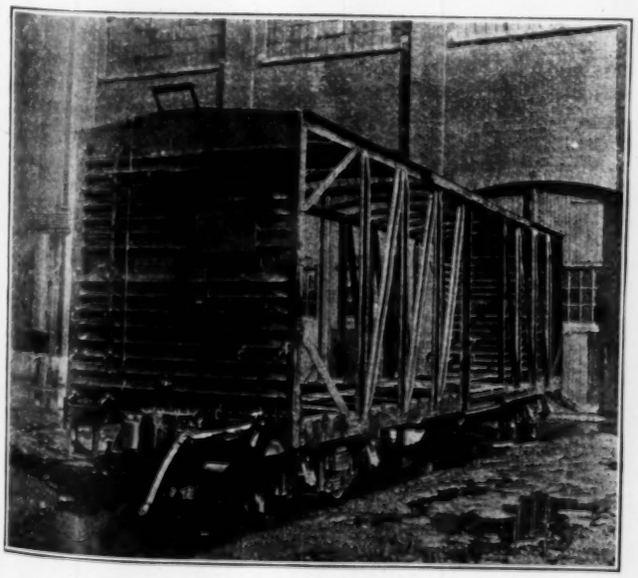

FIG. 6 CAR WITH STEELWORK COMPLETED AND READY FOR FINISHING

FIG. 7 CAR COMPLETED AND READY FOR SERVICE

of excessive load by varying the length of the punches, resulting in the holes being punched consecutively.

The usual practice for freight-car work is to punch rivet holes to a diameter not exceeding that of the rivet, and, when the parts are bolted together, to ream the holes to a size not exceeding that of the rivet by more than $^1/_{16}$ in.

THE JIG METHOD OF CAR-FRAME ASSEMBLY

The erecting of steel-frame box cars by the jig method was originated at the Angus shops. By this method the underframe, side frames, and end frames are assembled on jigs as complete units ready for the final assembly of the car. The jigs consist of stands or cradles by means of which the various members are accurately placed and held in proper relation to each other until they are riveted together. The advantages of this method are manifold. As each member lies flat in the jig, the drawing together of the parts is reduced to a minimum, wedge bolts being used extensively for this purpose as they can be rapidly applied. A complete unit being assembled in one operation, the possibility of accumulative error is avoided. The jigs dispense entirely with checking for squareness, alignment, and location of connection holes, thereby simplifying the final assembly to a considerable extent. Before any of the parts are assembled, all concealed surfaces are painted to prevent corrosion.

The center-sill channels after passing through slot-punching machine No. 763 are skidded from the idler rollers to trestles just inside the erecting shop, where the draft castings are temporarily bolted on and the holes reamed ready for riveting. An electric hoist operating on a runway below and clear of the overhead cranes, swings the sills into position and the draft castings are riveted on by a compression riveter. The individual sills are then moved across to a position on the left where the two center sills are assembled and riveted with bolster center castings and separators in position. The sills are placed on stands on which are four fixed pins corresponding to four rivet holes in the sills at the center line of the bolsters. By placing the sills flange down on these pins perfect alignment of the two sills is assured, which simplifies the application of cover plates later on. The draft gear is also applied in this position.

The next step is the assembling of the underframes, and as this is a lengthy operation, four positions are assigned for the purpose as indicated in Fig. 1. These jigs, as shown in Fig. 3, consist of four steel cradles located at bolster and cross-bearer centers, and so arranged that each member of the underframe is held in proper alignment and at centers that will coincide exactly with connections on the side frames. The bottom cover plates of the bolster and cross-bearers are first placed on centering pins; the overhead crane then places the center sills in position, to which are attached the bolster and cross-bearer diaphragms with their cover plates and center-sill cover plate complete, after which the assembly is bolted together and the holes reamed ready for riveting.

The underframes are then swung over by the overhead crane to the riveting jigs on the right, which are constructed similar to those used for assembling, thereby maintaining the proper alignment. Each riveting position is equipped with two 50-ton compression riveters suspended from swinging jib cranes, the posts of which are in line with columns to the right. The crane jibs are 21 ft. in length with runways for air hoists, the suspension mechanism being so arranged that the riveters can be tilted to drive the rivets in the inclined bottom flanges of the bolster and cross-bearers, which otherwise would have to be driven by an air hammer. The compression riveters were specially designed on the scissors principle, with a thin nose to permit of the top and bottom rows of rivets being driven without turning the underframe over in order to complete the operation.

The side frames, consisting of the side sill, side-plate, posts, braces, door posts, and track, are assembled as a unit on a jig frame situated abreast of the underframe jigs. This jig, as shown in Fig. 4, consists of channel-iron stands, the four corner ones of which are capped with short sections of channel iron in which are holes for locating exactly the side sills and plates. The stands on either side are tied together with angle bars which carry additional cross-bars upon which the various members of the side frames are placed in proper relation to each other. In this position the side frame is temporarily bolted, reamed, and riveted ready for the final assembly position.

Originally the end frames were assembled on jigs similar to those used for the side frames, but in recent years the end-post construction has been replaced by corrugated-steel ends. These steel ends and the end sills are assembled on trestles located between the final assembling tracks, and when temporarily bolted together they are skidded to the second and third positions where they are then reamed and riveted. In the fourth position the end ladders, roof-frame brackets, and other parts are applied, the ends as completed being then placed opposite the final assembling position.

ERECTING AND FINISHING THE CARS

As the trucks are assembled and painted, they are delivered from the truck shop and enter the erecting shop by the side door immediately ahead of the underframe and side-frame jigs, where they are turned on a turntable and placed in position on the assembling track. The underframe completed in the riveting jig is then lifted by the overhead crane and placed on the trucks, the slings are released, and a steel end is next placed in position and bolted on the end farthest away from the side-frame jigs; the side frames are then placed in position as in Fig. 5, and finally the second end, along with the center and side-sill cross-ties. The brake-cylinder reservoir and piping are also applied at this time.

The car is then moved by car haul to the second position where the assembled members and the roof framing are riveted in place. In the third position the safety appliances, brake rigging, couplers, uncoupling rods, etc., are applied, the remainder of the riveting completed, and the entire frame as shown in Fig. 6 is then sprayed with the priming coat of paint, when the car is ready for finishing.

The steel frames are switched each day to the wood freight-car shop where the decking, sheathing, roofing, and doors are applied and the painting operations are completed. The decking is of $1^3/_4$-in. red pine and the sheathing of $1^1/_2$ in. Douglas fir, both having tongued-and-grooved joints. High-grade lumber free from knots, checks, or cracks is selected for this purpose and is then kiln dried, the moisture content being carefully limited in order to prevent the possibility of further shrinkage later on; the only objection of any importance raised against the steel-frame box car, as compared with other box cars, having been one arising from improper drying of the sheathing.

Before leaving the planing mill the sheathing, roofing, and running boards receive their priming coat of paint in a painting machine recently developed at the Angus shops and which differs from those in use elsewhere. The boards on leaving the matcher pass automatically through this machine where they are sprayed by a series of nozzles which can be set in any desired position according to the surfaces required to be painted. The paint is drawn up through suction pipes from the bottom of the box by means of air jets blowing across the nozzles, and as ejected it is atomized by the air and blown on to the boards in the form of a fine spray. The amount of paint to be applied is controlled by air valves or by regulating the speed at which the boards pass through the machine. No brushing or wiping is necessary. The boards on leaving the machine are piled on trailer trucks and distributed by tractors to the shops when dry. These machines will paint at the rate of 200 running feet per minute, which is about as fast as the boards can be conveniently piled for drying.

The first operation in the wood freight-car shop is to apply the decking, the joints of which are previously coated with a thick paint compound, as are also the ends of the boards making contact with the bottom boards of the side sheathing previously applied.

The side sheathing which has already received the priming coat of paint is next applied, and to insure that the sides of the car will be watertight, the joints are coated with paint compound, after which they are wedged down into position and bolted to the framing. The end lining is then applied in a similar manner but vertically. In the succeeding operation the roof is applied, the boards and metal sheets of which have previously been primed.

After the doors are hung in place and the remainder of the safety appliances have been installed, the car is given two additional coats of paint and stenciled, when it is complete and ready for service, as shown in Fig. 7.

Recent Developments in Balancing Machines

By CARL RICHARD SODERBERG,[1] EAST PITTSBURGH, PA.

The balancing of rotating machinery is still far from being an exact science, although it has received a great deal of attention during recent years. The balancing of small high-speed motors for domestic use has been neglected to a great extent because satisfactory balancing equipment has not been available. The necessity for balancing this type of rotating apparatus is continually growing with the increase in speed and capacity and the customers' demands for a lasting product. The present paper is a brief description of efforts made to solve this problem and of a balancing machine finally developed that eliminated the difficulties and made it possible to manufacture quietly running motors.

SEVERAL fundamental difficulties, in addition to those encountered in balancing rotors of ordinary size, are involved in the problem of balancing small rotors.

a The balancing operation must be performed in a few minutes because the total cost of each unit is so low

b The high speed necessitates a very accurate balance

c The actual values of the centrifugal forces that are produced by a considerable unbalance are so low that it has been found extremely difficult to obtain an indicating device for the vibrating motion.

Because of these difficulties several attempts to produce a balancing machine for small armatures, operating on the usual principles of separating the static and the dynamic unbalance, have failed. It was decided, therefore, at the beginning of the investigation, to follow a plan that would procure complete balancing in one operation, without previous static balance. Arrangements of this type have been used before, but in these the balance is obtained by three weights, two of which cause considerable inconvenience in computing.

It is shown in an appendix to the complete paper that the general state of unbalance can be corrected by two masses, one in each of two transverse planes of the body. This can easily be understood by recalling the fact that any system of forces emanating from a straight line may be counteracted by two forces.

The most common type of balancing machine now on the market consists of a vibrating table so supported on springs and a fulcrum that the table is capable of performing small vibrations around a fixed axis. On this vibrating member are mounted the rotor to be balanced, a "dynamical image" of this rotor, usually consisting of a variable couple, and a driving mechanism for rotating the body and its image. If the fulcrum axis is parallel with the axis of rotation, the unbalanced dynamic couple is eliminated and the static unbalance can be ascertained and corrected. By shifting the fulcrum axis to a position at right angles to the axis of rotation, the remaining couple will be effective and may be determined and corrected. In both instances the vibrating table performs a forced vibration under the influence of the unbalanced forces in the body, and the amplitude of this motion is increased by adjusting the speed of rotation so that resonance occurs. Thus the sensitiveness of the machine is magnified without undue increase of speed. The original dynamic balancing machine, the squirrel-cage machine, devised by Akimoff[2] several years ago, was the first arrangement of this kind. Quite frequently the static balance is performed on parallel ways.

The static-dynamic balancing machine has the following fundamental disadvantages:

a The static balancing generally increases the magnitude of the unbalanced couple because of incorrect longitudinal location of the correction weights. Thus, the amount of balancing weights is greater than necessary

b The number of places in which correction weights are applied is frequently four and cannot be reduced to less than three, while the theoretical minimum is two

c Any error in the static balancing will have a serious effect on the determination of the couple. The effect of residuary static unbalance is frequently magnified on account of the large moment arm. In order to obtain a balancing result with a certain tolerance it is therefore necessary to perform the static balancing with exaggerated accuracy.

With the disadvantages in the existing equipment and the special requirements for the balancing of small rotors, the following demands were made on the new type of machine:

a Balance should be obtained by adding the theoretical minimum of weights to the body; that is, the two theoretical masses necessary for counteracting the system of unbalanced centrifugal forces should be given in the result

b The balancing operation should be performed with uniform accuracy; that is, the effect of one mass should be eliminated while the other mass is determined

c The balancing operation should take short time and be inexpensive, so that it can be applied to quantity production.

Balancing Machine with Movable Fulcrum

Fig. 1 shows schematically an arrangement whereby the general

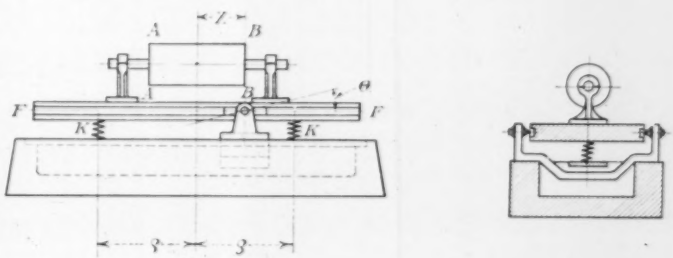

Fig. 1 Schematic Arrangement of Balancing Machine

state of unbalance may be obtained without segregation into static and dynamic unbalance. The body to be balanced is mounted in bearing blocks on a vibrating table supported by two spring members and a movable fulcrum member. This admits of motion around any axis in the plane *F-F* at right angles to the axis of rotation. Assuming that the transverse planes *A-A* and *B-B* have suitable arrangements for the application of correction weights, it is certain, from the above, that any unbalance in the body may be corrected by one weight in each of these planes. By placing the fulcrum axis in one of these planes, say, *B-B*, the theoretical weight in this plane is eliminated as far as its effect upon the motion of the vibrating table is concerned. This will now be produced by the unbalance in the other plane.

If a counterbalancing device for measuring the amount and the angular position of this weight is added to the arrangement, the unbalance may be determined in the same manner as static or dynamic unbalance is determined in the old type of balancing machine. By subsequently placing the fulcrum in the plane *A-A* the effect of the unbalance in this plane is eliminated, and the same procedure may be applied for determining the weight in the plane *B-B*. It is evidently of no importance whether the balancing weights are applied during the operation or not, since the effect upon the vibrating table is reduced in each case to that of one unknown weight. It is also evident that this arrangement meets the requirements.

This arrangement, which has been called a balancing machine with a movable fulcrum, was adopted as the most suitable one for balancing small armatures. There is, however, no indication that its application will be restricted to small rotors.

Features of the First Design

The subsequent design of an operative machine offered a number

[1] Engineer Motor Engrg. Dept., Westinghouse Elec. & Mfg. Co.

[2] Dynamic Balance, by N. W. Akimoff, Trans. A.S.M.E., vol. 38 (1916), p. 367.

Presented at the Spring Meeting, Montreal, Canada, May 28 to 31, 1923, of The American Society of Mechanical Engineers, 29 West 39th Street, New York, N. Y. Abridged. All papers are subject to revision.

of interesting problems. There are two possibilities with reference to the operation of the device:

a Determining the magnitude and the location of the unbalanced masses by means of a counteracting device

b Determining the magnitude of the unbalanced masses by the amplitude of the motion, and the location by "cut and trial" or by "marking" the rotor.

Although these two systems are different, they have no bearing upon the following theories. The first model was built and operated in accordance with the second alternative mainly because unbalance on the type of motors for which the model was built could easily be corrected by inserting wedges into the slots. It seems probable that, in this particular case, no gain could be obtained in speed of operation by applying a counterbalancing device. The following principles relate to either one of these alternatives and will be discussed separately for the sake of clearness.

Speed Variation for Different Locations of the Fulcrum Axis. Since the moment on inertia of the vibrating system varies with the location of the fulcrum axis, it is to be expected that the natural period, and hence the resonance speed, should vary. It has been found, however, that an arrangement can be made in which the restoring element receives a corresponding variation, so that the quotient remains constant. The theoretical explanation is given in a second appendix to the complete paper. Result of this investigation shows that if the two spring members are identical and located symmetrically with reference to the center of gravity of the vibrating bed and at a given distance, the natural period of the system is independent of the fulcrum location. Fig. 2 gives an illustration of the principle for the specific case where the center of gravity of the vibrating system is located in the fulcrum plane.

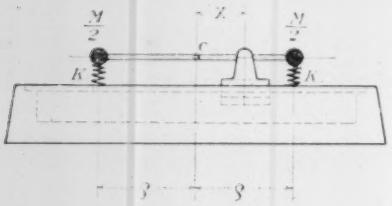

FIG. 2 SPECIAL CASE WITH CENTER OF GRAVITY OF VIBRATING SYSTEM IN FULCRUM PLANE

A constant balancing speed is very essential for efficiency and accuracy. The latter is largely dependent on the degree of resonance, and a slight error in the speed may distort the result altogether. The type of indicating device that was adopted served to increase the importance of constant speed.

Naturally the principle does not admit a variety of armatures to be balanced on the same set-up. As far as small rotors are concerned, they are manufactured in large lots, thus making it necessary to have a balancing machine for each type. When frequent changes have to be made, a vibrating table may easily be supplied for each type of armature.

Indicating Device. The indicating device proved to be a stumbling block. Attempts to use the ordinary type of dial gage indicators failed altogether. There was always the possibility of using the conventional mirror and light beam, but it was not considered practical in production routine. A vibrating reed was finally applied with success. Spring steel 0.125 in. by 0.006 in. is used on the present model and the amplitude of the reed is a tolerably good measure of the angular deflection of the vibrating bed. The resonance of a reed of this type is considerably sharper than the resonance of the vibrating table itself. This is a decided advantage, because erroneous readings are eliminated. It necessitates, however, a constant speed of the driving arrangement.

Driving Mechanism. The requirements for constant speed magnified the importance of the driving motor. Several attempts were made with a small motor mounted on the vibrating table, but without success. The kinetic energy of the rotating masses must be sufficient to resist variation in the friction load. As long as the driving motor is mounted on the vibrating table, its weight must be restricted in order that the vibrating mass may not be too great. In the arrangement used at present the rotor is being driven by a fairly large a.c. motor mounted on the solid foundations. The driving belt consists of a silk ribbon. This arrangement has proved to be satisfactory. The disturbance of the belt is not sufficient to influence the motion of the vibrating bed.

Predetermination of Sensitiveness. The problem of predetermining the amplitude for a given unbalance necessitates a closer study of the factors that limit the motion at resonance, and a better knowledge of the internal friction of springs is therefore of extreme importance. Little work has been done along this line, however, and there are no reliable methods available for the predetermination of the internal friction in springs. It is generally assumed that the damping of a spring is a linear function of the speed, and this appears to be fairly true for small motions. A variation of the spring characteristic for different degrees of compression will also limit the amplitude at resonance, although in a manner different from that of internal friction. If this variation is large it may seriously impair the resonance. The requirements of springs for balancing machines are therefore:

a Straight-line characteristics

b Low internal friction.

The relation of the amplitude, that is, the angular deflection of the vibrating bed, to the unbalanced moment is explained in a third appendix to the complete paper. It is shown that the angular deflection is directly proportional to the unbalanced moment with regard to the fulcrum axis and inversely proportional to the damping factor. This is true for perfect resonance and for the assumption that the damping is proportional to the first power of the speed. It has also been found in this investigation that the major part of the damping effects occurs in the springs themselves. The total damping is therefore a function of the location of the fulcrum axis. The minimum of damping occurs at the central location of the fulcrum. Therefore the amplitude is not a direct measure of the unbalanced moment; it is always possible, however, to place the rotor in such a manner that the readings have the same value for the two planes in which the unbalance is corrected, because the variation of the damping factor is symmetrical with reference to the central location of the fulcrum.

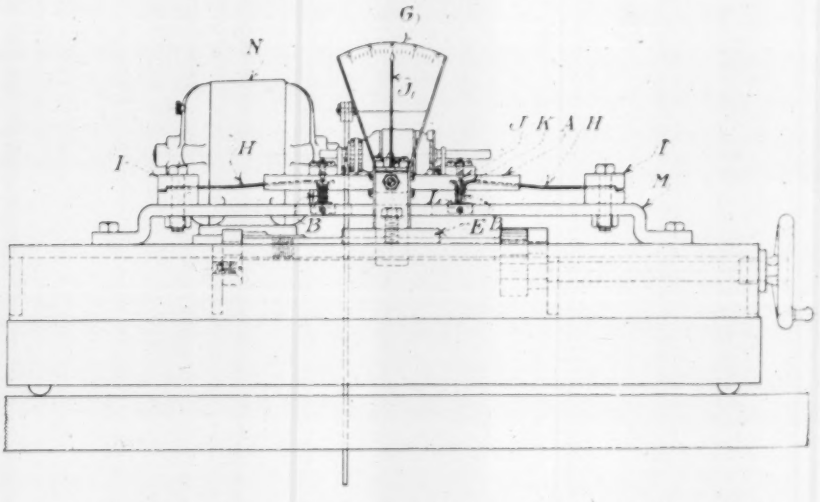

FIG. 3 SIDE VIEW OF BALANCING MACHINE WITH MOVABLE FULCRUM

There is, however, another factor of importance in this connection. It is theoretically true that if the springs have straight-line characteristics and a sufficiently low internal friction, a small disturbance (unbalance) will produce a considerable amplitude. If the disturbance is small, however, the time required by the vibrating system to absorb sufficient kinetic energy to attain its maximum amplitude will increase. This introduces another element into the problem, namely, the proportion between the moment of inertia of the vibrating system and the magnitude of the disturbance. Common sense tells us that there is a certain limit to the moment of inertia of the vibrating system for each amount of unbalance to be measured, but no attempt has previously been made to establish actual values. In the author's

opinion, the time required for the balancing machine to "pick up" and the amount of internal friction are the two elements that enter into the question of sensitiveness. It is shown in a fourth appendix to the complete paper that this time element is largely dependent on the quantity $P\,I$; that is, the proportion between the unbalanced moment and the moment of inertia of the vibrating system. The minimum value of $P\,I$ will thus be a logical measure of the sensitiveness of the balancing machine. Below are given minimum values of $P\,I$ that were obtained in the model with a movable fulcrum and three other balancing machines of the usual type.

	Value of $(P\,I)_{min}$
1 Model with movable fulcrum	15×10^{-6}
2 125–500-lb. balancing machine	0.6×10^{-6}
3 500–3000-lb. balancing machine	0.45×10^{-6}
4 3000–10,000-lb. balancing machine	0.4×10^{-6}

These values were obtained by experiments on the balancing machines. They are influenced, therefore, by the following factors:

a The nature of the indicating device
b The damping factor
c The actual value of the moment of inertia of the vibrating system with regard to the axis of oscillation.

The model with a movable fulcrum has an indicating device which records the angular deflection of the vibrating bed so that only the sensitiveness of this device (amplitude per radian) enters into the expression $P\,I$. The other machines, however, are equipped with dial gage indicators so that in the sensitiveness of the indicator is also included its distance from the axis of oscillation. This distance is usually made as large as possible. The larger machines therefore have the advantage of a more sensitive indicator. The dial gage indicators on these machines are all of the same type. A total amplitude of 2 deg. (0.002 in. linear motion) is considered the minimum detectable motion.

The damping factor and the moment of inertia are variable in the model with a movable fulcrum. Therefore, the value of $P\,I$ refers to the central location of the fulcrum.

The balancing machines in cases 2, 3, and 4 are of the same type. They show a tolerable consistency in the minimum value of $P\,I$ with a slight increase for the lower capacities. The model with a movable fulcrum has a capacity of an entirely different order and the value of $P\,I$ is increased correspondingly. This

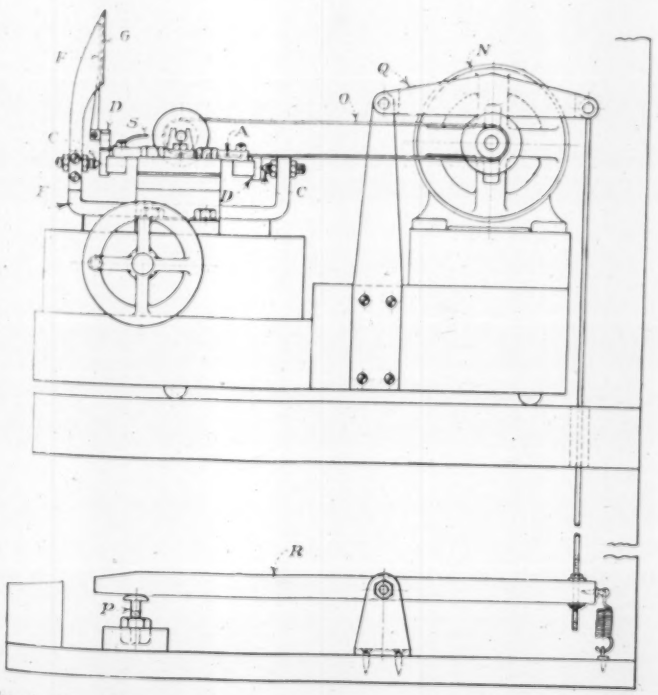

FIG. 4 END VIEW OF BALANCING MACHINE WITH MOVABLE FULCRUM

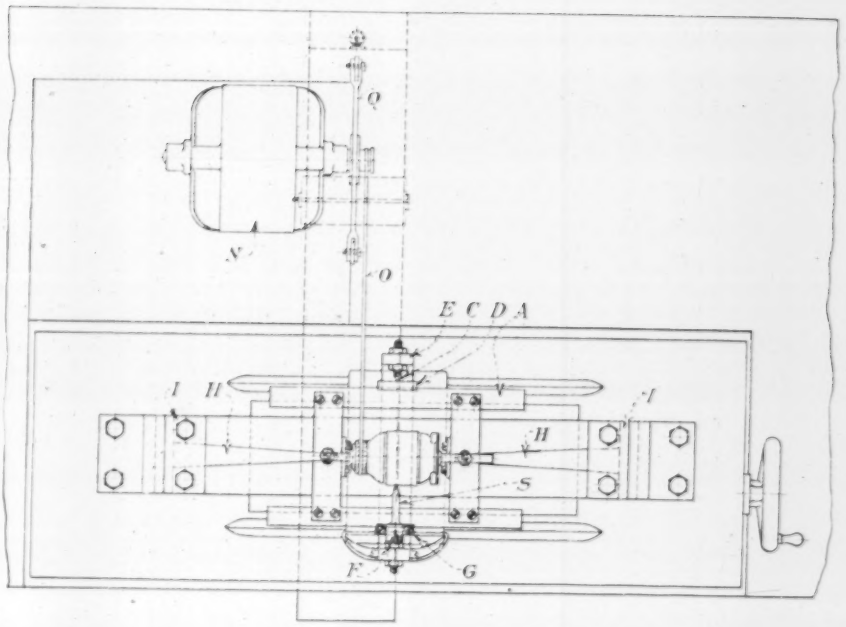

FIG. 5 PLAN VIEW OF BALANCING MACHINE WITH MOVABLE FULCRUM

illustrates the difficulty in obtaining an accurate balance of small rotors. In order to keep the minimum unbalance sufficiently low it is necessary to have the moment of inertia of the vibrating system exceedingly small.

It would be highly desirable if the limiting values of $P\,I$ could be learned when a balancing machine is purchased. The buyer would then be able to tell if the lower limit is consistent with the accuracy of balancing that he wishes to obtain on the smallest rotor to be balanced. At the present time balancing machines are rated with reference to the maximum and minimum weights of rotors to be balanced. The upper limit may be necessary from the point of view of stresses in the mechanical structure. The lower limit does not, however, give reliable information with regard to the accuracy of balancing.

DESCRIPTION OF FIRST MODEL

Figs. 3, 4, and 5 show a balancing machine with movable fulcrum adapted to balance an electric armature weighing about 9½ oz. Fig. 3 is a side view, Fig. 4 an end view, and Fig. 5 a plan view. The machine is shown mounted on a working bench with a foot-operated starting and braking arrangement of the driving motor.

The vibrating bed A is supported by the coil springs B and the pivots C. These pivots engage in centers on the sliding blocks D so that by moving the carriage E the axis of oscillation is moved relatively to the armature. The location of the pivots with reference to the armature is indicated by the pointer S. One of the sliding blocks carries the vibrating reed F, which vibrates across the graduation on the scale G attached to the carriage E. The indications of the reed are therefore proportional to the angular deflection of the vibrating bed.

The bed is prevented from moving in the horizontal plane by the flat springs H, clamped in the blocks I. These flat springs press against the knife edges J which have center pins engaging in centers on the caps K of the coil springs. The flat springs have slots to fit these pins. The slots are machined so that there is practically no clearance in the lateral direction but a considerable clearance in the longitudinal.

The coil springs are supported on the longitudinal member M by the adjustable seats L. Thus the length of the springs may be adjusted so that the entire weight of the vibrating system is carried by the springs. In this case the pivots carry no other load than that of the inertia forces. The carriage E moves underneath the spring-supporting member M. This admits of moving the fulcrum member past the springs if desired.

The driving motor N is a single-phase induction motor starting as a repulsion motor. The load is very small so that it runs at

(*Continued on page 383*)

The Development of Industrial Safety Codes

By M. G. LLOYD,[1] WASHINGTON, D. C.

After giving statistics showing the need for accident-prevention work from both the humanitarian and the economic viewpoint, this paper shows the value of state inspections and national codes. It then presents a brief history of the American Engineering Standards Committee's activity in this field and of the Safety Code Correlating Committee. The paper closes with an outline of the manner in which safety codes are now formulated.

THE PAST dozen years have shown a growing interest in accident prevention and a rapid development of activities for the elimination of casualties. The extension of compulsory compensation laws, which now cover all but the District of Columbia and five states of the Union, has given accident prevention in industry an economic status which it did not previously possess. Prior to this era claims for damages by employees could be resisted in the courts by employers and the defense of contributory negligence acted to eliminate many such claims. Under the present compensation laws, however, the payment of such claims has become more certain and definite in amount. Compensation insurance is very general and its cost is in most cases dependent upon the accident experience of the policy holder. There is consequently a very definite economic incentive for the reduction of industrial accidents.

In the fiscal year ended June 30, 1920, the Federal Government spent about $1,350,000 for accident prevention and sanitation work in industry, representing an expenditure of about 1.3 cents per capita. The part of this amount used for accident-prevention work in the manufacturing industries represents an expenditure of about 8 mills per thousand dollars of value of manufactured products. In the case of mineral products the disbursement is about 9.5 cents per thousand dollars of value of products.

Most of the states have a department of labor or industrial commission administering compensation, and many of them have authorized such commissions to undertake work for the prevention of accidents or else provide an independent state factory inspector. In 1919 the various states spent for accident-prevention work $2,723,000, or about twice as much as the Federal Government spent for safety and related purposes.

No reliable estimate can be made of the amount of money expended each year by the industries themselves in improving the physical conditions of their plants and in other activities related to accident prevention. In addition to such expense they must also meet compensation costs, attorneys' fees, and other expenses occasioned by accidents. The expenses of many individual corporations annually in connection with accidents and safety work mount into six figures, and the total for all industries must run into many millions. The railroads of the country alone paid out in 1917 over $33,000,000 chargeable to accidental injuries. There were in that year 10,087 fatalities and 210,729 cases of injuries. The average cost was thus over $150 per accident.

This immense waste of human resources has both a humanitarian and an economic aspect. The economic waste involved is of great importance to industry. So far as it depends upon physical conditions of plant equipment and operation it can be largely eliminated by compliance with the principles of accident prevention which it is the function of safety codes to apply in detail to specific industries or operations.

State Inspection

The principal activity by which the state officials can reduce accidents is the inspection of factories and other work places and insistence that they shall be so constructed and operated as to provide for the safety and health of employees. In making such inspections it is necessary that the inspector should have some standard of comparison by which to judge of the conditions which he encounters. Only by having such a standard of reference is it possible for different inspectors to treat different cases upon a uniform basis or even for a single inspector to be consistent in his decisions with reference to different industrial plants. Such a standard may exist only in the mind of the inspector and be subject to development and change from day to day. Much more satisfactory results, however, can be obtained by having written standards subject to change only by definite action of the administrative authority and capable of being known to factory managers, manufacturers of machinery, and others concerned with them before installations are made. It is then possible for such persons to plan their installations so as to meet the requirements of the state officials. In that way more complete compliance on a more satisfactory basis is obtained.

It will be apparent that the greatest satisfaction to both inspector and factory manager will result from inspections and the enforcement of regulations when the latter consist of a definite set of written rules which have been given full consideration before adoption and which are applied uniformly by all inspectors within a given jurisdiction and are modified only by definite administrative action after due notice and full consideration. Consequently most of the states which are active in factory-inspection work have definite regulations, and it is the duty of their inspectors to see that such regulations are complied with.

These regulations may take the form of statute laws or of rules promulgated by some administrative authority. Where the regulations are established by statute it is impossible to alter or amend them except by the same legislative process. Where the regulations are promulgated by administrative authority, changes and amendments can be made from time to time as experience or progress in the art makes it advisable to do so, and a system which is more flexible and in general more satisfactory to all parties concerned is obtained.

Whatever legal form the regulations may take, it is desirable that they be as definite as possible, be so drawn up as to be easily understood, be available in printed form for the guidance of all interests concerned, and be given very thorough consideration by all parties and interests before their mandatory adoption.

Such a code of safety rules is valuable not only for mandatory enforcement by administrative authorities and for authorized inspectors, but as a guide to the industry concerned in improving its methods and modifying its previous practices. Many manufacturers are only too glad to make improvements in the physical condition of their plants when the possibility of such improvements is pointed out to them, and many of them are eager to apply any information which will improve the welfare of their employees. The greatest value of the safety code is probably in providing such information as a standard for the guidance of the factory manager, and the author considers its usefulness as a regulation for legal enforcement to be secondary to this.

Advantages of National Codes

Most of the safety codes heretofore adopted and enforced by state boards and commissions have been developed locally and usually with the coöperation of a committee representing local interests. In the preparation of such codes, use is frequently made of standards already adopted by other states or by industrial and engineering associations. In some cases such standards already available are adopted without change, but more often changes of greater or less extent are made for the purpose of improvement or of meeting some real or fancied need caused by local conditions. This is well illustrated by the Boiler Code prepared by The American Society of Mechanical Engineers and the Electrical Safety Code prepared by the Bureau of Standards. If the national codes were generally prepared by processes which would take into consideration local variations and conditions, and which guaranteed the full consideration of the viewpoint of every interest involved and freedom from domination by any one interest, particularly such as might

[1] Chief of Safety Section, U. S. Bureau of Standards; vice-president, American Society of Safety Engineers.

Presented at a joint session of the American Society of Safety Engineers and the A.S.M.E. Safety Codes Committee at the Annual Meeting, New York, December 4 to 7, 1922, of The American Society of Mechanical Engineers. Slightly abridged. All papers are subject to revision.

be of a commercial character, it would seem advantageous to adopt such national codes without the introduction of local variations. This would give the advantage of uniformity in requirements in different jurisdictions. The manufacturers of equipment could then supply a single line for use in all states, thus reducing production costs, and the work of the contractor and inspector would be simplified. It would also be easier for the insurance companies to harmonize their own requirements with those legally enforced by the state authorities. As it has been in the past, and is now, the requirements of state inspectors and insurance inspectors are frequently different, resulting in confusion and friction, and a disinclination upon the part of the factory manager to comply with either. If these standards were made uniform, and all concerned with safety agreed upon the physical conditions for attaining it, there would be greater readiness to follow such standards in practical shopwork.

To obtain national codes of this character it is necessary that their preparation be accomplished by the widest and most thorough consideration of those familiar with the particular problems of the industry concerned and that full weight be given to the viewpoints of all interests involved.

Realizing the importance of safety codes prepared upon a national basis, and as the result of the contacts made by its previous work in this field and the demands for more extensive work of the same character, the Bureau of Standards called a preliminary conference on this subject in Washington in January, 1919, and a second conference in December of the same year. At these conferences the subject was fully discussed, the need for national codes generally recognized, and the best method for preparing them given full consideration. It was finally agreed that the scheme of procedure in establishing national standards which had been inaugurated by the American Engineering Standards Committee would be the most satisfactory to utilize in the preparation of safety codes, and it was finally voted by a large majority that they should be prepared under the auspices of this committee. It was realized, however, that in order for this plan to be widely acceptable it would be necessary to enlarge the scope and membership of the American Engineering Standards Committee, and this was done as a direct result of these conferences.

Safety Code Correlating Committee

As a result of the 1919 conferences a National Safety Code Committee was formed which is now known as the Safety Code Correlating Committee. It acts as an advisory body to the American Engineering Standards Committee in all matters relating to safety codes, its membership being such as to give it more direct contact with the desires and needs of those most intimately concerned with safety matters. Its present membership includes representatives of the following:

American Gas Association
The American Society of Mechanical Engineers
American Society of Safety Engineers
Association of Governmental Labor Officials
International Association of Industrial Accident Boards and Commissions
National Association of Mutual Casualty Companies
National Bureau of Casualty and Surety Underwriters
National Electric Light Association
National Fire Protection Association
National Industrial Conference Board
National Safety Council
U. S. Bureau of Labor Statistics
U. S. Bureau of Mines
U. S. Bureau of Standards

The first report of this Committee in 1920 included a list of thirty-seven codes which were considered of the most immediate importance and for which sponsor bodies were recommended. Since that time it has made additional recommendations from time to time and the Engineering Standards Committee has referred to it questions concerning safety codes which required investigation before decision.

The members of the Safety Code Correlating Committee are frequently designated by the chairman of the Engineering Standards Committee to serve upon special committees which investigate the make-up of Sectional Committees for safety codes or advise the Engineering Standards Committee as to the suitability of approval of standards in this field which have been submitted to it. The Committee thus functions in general to advise the Engineering Standards Committee and keep it informed when necessary on matters relating to the field of safety codes.

The Preparation of Safety Codes

When, after recommendation from the Safety Code Correlating Committee, the American Engineering Standards Committee recognizes the need for the development of a particular safety code, it designates one or more sponsors to manage the formulation of such a standard and the sponsor body organizes a Sectional Committee containing representatives of all organizations which are considered to have an interest in the development of this particular code. Such Sectional Committees usually contain representatives of the following groups of interests:

Manufacturers of the equipment
Employers
Employees
Regulatory government representatives
Technical experts
Casualty-insurance companies

The Sectional Committee must have its make-up approved by the American Engineering Standards Committee as being properly representative and well balanced as to interests which may have different viewpoints. This Sectional Committee may itself carry out the work of formulating a standard or it may merely pass upon such work when it has already been done, and is free to modify any standard before its adoption. When the Sectional Committee agrees that a standard or code is in acceptable form for final adoption it reports to the sponsor, and if the sponsor body is satisfied with its work and approves it, it so reports to the American Engineering Standards Committee. That Committee then approves the standard as an American Standard, as a Tentative Standard or as Recommended Practice.

The American Engineering Standards Committee has already approved eight standards which may be classed as safety codes, as follows:

Industrial Lighting Code
Safety Code for the Use, Care, and Protection of Abrasive Wheels
National Safety Code for the Protection of the Heads and Eyes of Industrial Workers
National Electrical (Fire) Code
National Electrical Safety Code
Foundry Safety Code
Power Press Code
Permissible Explosives

More than twenty other safety codes are now being actively worked upon and some of them are about completed. Almost an equal number in addition have been given preliminary consideration.

It will be apparent from the foregoing that the American Engineering Standards Committee, with the coöperation of the Safety Code Correlating Committee, furnishes the machinery for the formulation of safety codes in a manner which will insure thorough consideration of the merits of proposed rules and thorough consideration of the viewpoint of the various interests which are concerned with safety codes. The actual formulation of such codes may be by a Sectional Committee, by a working sub-committee of such Sectional Committee, or by the technical staff of a sponsor body, but in every case the entire Sectional Committee must pass upon the work and approve the tentative draft of a code before it is submitted to the American Engineering Standards Committee. The Sectional Committees are made up of representatives from the six groups previously mentioned and in the case of safety codes always include some representatives from state departments of labor or industrial commissions. When such codes have been approved by the American Engineering Standards Committee the assurance is given that they have had just as thorough consideration as is ever given locally to the formulation of a state code, and in most cases they will have had wider consideration and criticism; and in adopting such a code any state authority may feel sure that he is putting into effect as reasonable and as complete a set of rules as it is feasible to formulate at the time. Such codes may consequently be taken as models for local adoption and application and there will usually be no good reason for modifying the form in which they have been nationally approved.

SURVEY OF ENGINEERING PROGRESS

A Review of Attainment in Mechanical Engineering and Related Fields

AERONAUTICS

THE REED SOLID-METAL SEMI-FLEXIBLE PROPELLER, S. Albert Reed. Description of a new propeller which is said to be marketed by the Curtiss Company. It is a semi-flexible, solid, thin one-piece metal propeller of about the same weight as a wooden propeller. It is claimed that it can be twisted to varying pitches and twisted back again, permitting combinations of two-bladed propellers to make four at will and turning at the velocity of sound.

The original article describes in some detail the principles underlying the design and tests made with the propeller, particularly those at McCook Field. (*Aerial Age*, vol. 16, no. 4, Apr., 1923, pp. 182–185, 6 figs., *d*)

LIGHT PLANE AND GLIDER NOTES. A competition probably to be held some time in September has been arranged for in England for light planes fitted with engines not exceeding 750 cu. cm. capacity.

In this connection it is stated that Barbot has been recently flying at Toulouse, France, with a machine fitted with a 7–10-hp. motorcycle engine. He took it up to a height of about 1500 ft. and made a cross-country flight. It is further stated that the machine requires only 4 hp. to keep it in the air and that the maximum speed is about 60 miles per hour. The machine is called the "Dewoitine."

In England a light plane has been designed by W. O. Manning for the English Electric Company and fitted with a two-cylinder A.B.C. motorcycle engine nominally of 4 hp. but developing about 7 or 8 hp. This machine was tested by Squadron Leader Morris Wright, first in straight flight and then in a flight of seven minutes' duration with satisfactory results.

The "Wren," as this design is called, is an ordinary glider in appearance with enclosed fuselage and a cantilever wing with a pronounced dihedral, and the under carriage nearly hidden in the fuselage. The engine drives directly a tiny tractor screw.

In this glider both the pilot and the engine are in front of the wing and yet the machine is not nose heavy, which may be due to the fact that the tail is set at a large negative angle. (*Flight*, vol. 15, no. 15, 746, Apr. 12, 1923, pp. 199–200, 2 figs., *d*)

Lacierva Autogiro Aeroplane

NEW TYPE OF FLYING MACHINE—THE LACIERVA AUTOGIRO. Description of a machine designed by the Spanish inventor Juan Lacierva and tested near Madrid by an officer of the Spanish army.

The "Autogiro," as the machine is known, is not a helicopter. In it the large four-bladed screw which is mounted on the vertical shaft fixed on the fuselage is not actuated by any power plant. Instead it is made to turn freely on its bearings. It is therefore really a wind vane which operates like the small propellers which are used to actuate the fuel pumps of aircraft engines or wireless generators.

This big vane is mounted in ball bearings and is not controlled by the pilot. The blades of the vane are set at a fixed angle of incidence relative to the axis of rotation, but they are hinged to the bearing shaft in such a way that in flight they place themselves in the resultant of their lift and the centrifugal force.

Outside of these vanes the machine is an ordinary tractor aeroplane. The following is given to explain the principles involved in its operation.

It is known from experiments that when a stationary airscrew is exposed to an air current, the blades, being in position *A* (Fig. 1), have a resultant *R* which makes an angle with the airscrew shaft. The resultant *P* of the opposite blade (position *B*) has always a smaller angle than *A* or is negative. Therefore a rotation is established by the airscrew in the sense of the arrow. The speed of rotation will increase until the resultant of *R* and *P* is parallel to the axis of rotation of the airscrew. The whole lifting body does not transmit to its shaft any torque except the one produced by the friction of the bearings, which can be neglected, therefore eliminating the necessity of using two propellers.

However, the resultant velocity of the blades relative to the air in position *A* is greater than in *B* and its lift will be greater also. Therefore the total resultant of this airscrew will not pass through its center and the whole system will tend to bank. This banking effect has been overcome in the Autogiro by fixing the

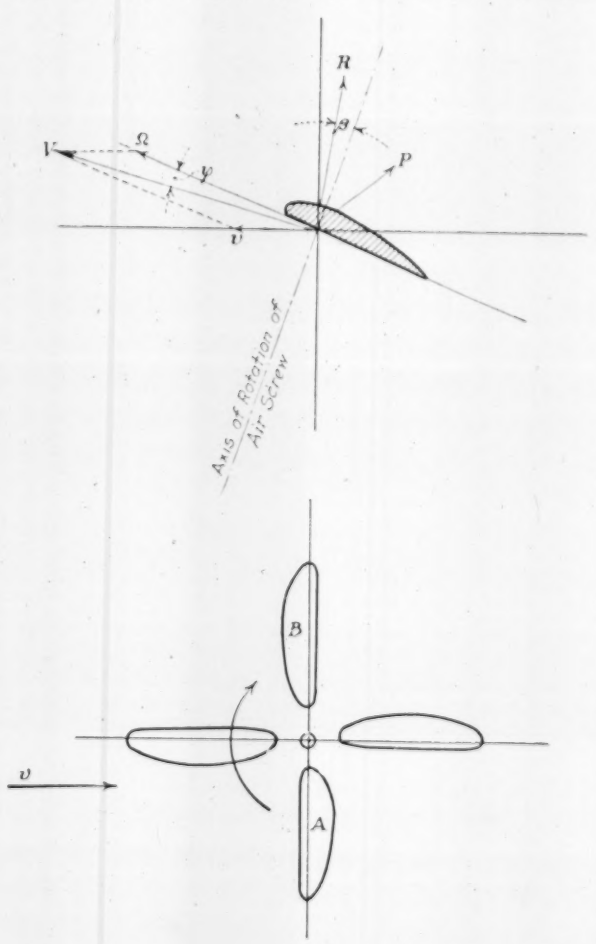

FIG. 1 WIND VANE OF THE LACIERVA AUTOGIRO

blades to the shaft by means of a hinge, which permits them to set themselves automatically in the resultant position of the centrifugal force and lift. In such a way blades *A* will bank slightly, while blades *B* will remain horizontal and the total resultant of the lifting airscrew will always pass through its center.

If we analyze the effect of the hinged blades of the vane, we see that the shaft can freely change its angle with the plane of rotation of the blades, but that the blades have a strong tendency to return to their original position relative to the shaft. This gives an automatically perfect banking in the turns and stability in flying.

The velocity of the blades relative to the air is much greater than the translational speed of the whole machine. The angle of attack is a function of the translational speed of the machine and the angle between its direction of motion and the plane of rotation of the blades. This allows a much greater range of speeds and angles of flying to the whole machine, and will permit landings in very small spaces without horizontal motion.

It is stated that in tests it did land with the engine shut off with practically no forward speed and that it has remarkable stability for it can be flown without assistance of any lateral control while the elevator controls could be locked for any length of time without influencing the behavior of the machine. (*Aviation*, vol. 14, no. 15, Apr. 9, 1923, pp. 397-398, 2 figs., *d*.A)

BUREAU OF STANDARDS (See Engineering Materials; Refrigeration)

ENGINEERING MATERIALS (See also Refrigeration)

West African Palm Oil—Manufacture and Uses

WEST AFRICAN PALM OIL, "Agricola." Down to quite recent years virtually the whole of the palm oil produced in West Africa has been laboriously and crudely prepared by hand labor, chiefly that of women and girls, while the quality of the product has been admittedly below attainable standards; moreover, it has long been known that enormous quantites of oil are lost annually in consequence of the wasteful methods adopted.

The situation would seem to present a splendid opportunity for the introduction of machinery, and it is remarkable that only within the last decade or so have serious attempts been made to tackle the question.

At the present time, however, serviceable machinery is being employed which removes the pericarp from the fruits, the oily pulp being then transferred to presses where the expression of the oil is effected under controlled conditions of temperature.

The employment of such machines effects great economies in production, and also results in the production of a clean oil of good, dependable quality. So far, plant of this kind is almost entirely in the hands of European companies.

The palm "nuts" which were separated from the oily pericarp, and set aside for subsequent treatment, have now to be dealt with in order to obtain the kernels.

As the first step, the nuts are spread out in the sun for a week or more in order to cause the kernels to shrink from the shells and so render their removal easy.

The subsequent procedure, however, is almost incredible. Millions upon millions of palm kernels are exported from West Africa every year, yet, until comparatively recently, every single kernel has been obtained by the deliberate cracking by hand, between two pieces of stone, of the separated individual nuts, one by one, followed by the picking out, separately, of the individual kernels.

Effective machines for this purpose are now available, but in spite of their increasing use (chiefly by European undertakings), the great bulk of the palm nuts are still cracked by hand.

The kernels are collected and shipped to Europe where the oil is obtained either by pressure in machine presses, or extracted by solvents from which the oil is obtained subsequently by evaporation.

The nut shells form a good fuel, but at present have no regular industrial use. During the war, however, palm-nut shells (as in the case of cocoanut shells) were largely used for the manufacture of a charcoal which was found to be admirably suited for use in gas masks as an absorbent of noxious fumes.

The primary value of palm oil to the West African native is as a foodstuff which is chiefly used as an oily basis for the preparation of soups, stews, and dishes of all kinds; and "palm-oil chop" is familiar enough to Europeans on the Coast.

The oil used for this purpose is usually carefully prepared from fresh fruit, and has considerable dietetic value. When fresh it has an odor of violets, and is much appreciated by the natives.

In certain districts the natives are also acquainted with the use of the oil for making soap, which they prepare by mixing the oil with ashes obtained by burning banana leaves. This fact is interesting, since the manufacture of soap and candles is one of the chief uses to which palm oil is put in industrial Europe, especially in this country, where enormous quantities are employed for soap making.

Another important use is in the Welsh tin-plate trade, where palm oil (commonly mixed with cottonseed oil and certain mineral oils) is extensively used for coating the heated iron plates previous to the "tinning" process, in order to prevent oxidation. It will also be remembered that, as mentioned in a recent issue of *Imperial Commerce*, oil engines have now been designed which successfully use palm oil as a fuel.

The oil from the kernels (palm-kernel oil) finds somewhat different uses. Like palm oil it is solid fat (white) at temperatures obtaining in this country. Relatively small quantities of the kernels are used locally, the bulk being exported.

Before the war this trade was very largely in the hands of Germany, as is shown by the fact that in 1913 of a total export of 174,720 tons of palm kernels from Nigeria, valued at £3,109,820, no less than 131,886 tons, valued at £2,405,624, were sent to Germany, the British import being only 30,345 tons valued at £511,541. Further, Germany in the same year obtained an additional 100,000 tons of kernels, worth over £1,000,000 from other West African countries, British and foreign. During the war, however, the kernels were sent to this country and an important trade in them has been built up which it is hoped will be retained.

Two products are obtained from the kernels, viz., white palm-kernel oil, and oil cake.

The oil has a pleasant nutty taste and is used not only for making soap and candles but also to an increasing extent for the manufacture of margarine, vegetable butters, cooking fats, and fats used in making chocolates and confectionary. The oil is well suited for margarine, and it is estimated that probably 40,000 tons are now used annually in Europe for this purpose.

The oil cake is a most valuable feeding stuff for live stock and is especially useful as a food for dairy cattle, for which purpose it was highly prized in Germany and other European countries. In this country, however, it is by no means widely known. (*Imperial Commerce and Affairs*, Aug., 1922, abstracted from a publication of the Bureau of Foreign and Domestic Commerce, Department of Commerce, 9 pp., *gd*)

Chromizing

CHROMIZING, F. C. Kelley. Paper giving a brief summary of the work which has been done to date on the diffusion of metals in the solid state and describing in detail the process of chromizing and its effects on the physical and chemical properties of iron.

The method of chromizing described by the author is somewhat similar to the well-known process of calorizing and depends upon the property possessed by many metals of diffusing at temperatures below their melting points.

The process consists of packing the material to be treated into a powdered mixture of alumina and chromium. The amount of the material used in the mixture is 45 per cent of alumina and 55 per cent of chromium by weight. The material is usually packed into a tube of iron, and then heated at 1300 to 1400 deg. cent. in hydrogen, in vacuum, or in some neutral atmosphere for a length of time depending upon the penetration and concentration of chromium desired. Certain precautions as to the presence of oxygen and water vapor have to be observed.

The furnaces used for this work consist of alundum tubes wound with molybdenum wire as a heating wire. These tubes are placed in a suitable furnace casing and surrounded with alumina powder, which acts as a heat-insulating material. The chief use for these furnaces thus far has been in the chromizing of turbine buckets, which latter have been installed in various turbines throughout the country in order to test them for corrosion under actual operating conditions.

The structure of the metal is next discussed and illustrated by photomicrographs. In order to get the best results it is necessary to use an iron or steel of low carbon content, as iron of high carbon content does not chromize well. The difficulties of the process are discussed and data given as to the penetration of the chromium into the material.

As regards resistance to corrosion, chromized-iron samples were tested alongside with sherardized samples and gave equally good results.

The samples under test showed up so well that additional tests upon turbine buckets were made. These chromized nickel-steel buckets proved so satisfactory that it was decided to put them into various turbines throughout the country, and into some of the turbines of ocean-going vessels. The best comparison of

resistance to corrosion of chromized and unchromized turbine buckets under service conditions is illustrated in a figure in the original paper. These buckets were run side by side in the same wheel of a turbine for one year. The unchromized nickel-steel bucket had its edge entirely corroded and eroded away, and in addition the face of the bucket was badly corroded. The chromized bucket was in perfect condition, showing no signs of corrosion.

In cases where the chromized material must stand high tension and fatigue stresses, the high temperature of chromizing lowers the resistance of the material to these stresses, but by proper heat treatment the original properties may be almost entirely restored.

Carbonizing of chromized iron lowers its resistance to corrosion, and polished samples of chromized iron which have been case-hardened will show numerous globules of water if allowed to stand in the open air for only a short time.

Chromized iron itself is quite soft and ductile, but by case-hardening and heat treatment it may be made very hard.

Chromized-iron samples were tested in 10 per cent HCl, HNO_3, and H_2SO_4. They stood up for five months in the 10 per cent HNO_3 without discoloring the solution or showing any signs of attack, but they broke down almost immediately in the other two acids.

In addition to these characteristics, chromized iron has a silver color, it takes a high polish, and the most remarkable thing about it is its softness, even where large percentages of chromium are present.

Chromium may be applied to other metals besides iron and may be used for purposes other than preventing corrosion. (Paper presented before Forty-third General Meeting of the American Electrochemical Society, May, 1923. Abstracted from advance copy, pp. 233–250, 8 fig., *eA*)

Lathe Breakdown Tests of Some Modern High-Speed Tool Steels, H. J. French and Jerome Strauss. This report is concerned with comparisons of performance of modern high-speed tool steels in so-called "lathe breakdown tests," in which endurance of tools is measured under definite working conditions, and likewise with the limitations of this method when applied to the purchase of steel. The modern steels are first classified according to chemical composition, and this division is made use of in discussion of results obtained.

Important features developed or conclusions drawn may be summarized as follows:

1 Breakdown tests are not satisfactory as the basis of purchase for high-speed tool steels.

2 While competitive comparison of brands of nearly similar performance are not justified, owing to the qualitative nature of this type of test, relatively large differences may be ascertained with certainty, provided sufficient tools are tested and averages of at least two grinds are used in the interpretation of results.

3 In certain severe breakdown tests with roughing tools on 3 per cent nickel-steel forgings, in which high frictional temperatures were produced, it was found that the performance of commercial low tungsten-high vanadium and cobalt steels was superior to that of the high tungsten-low vanadium type, and special steels containing about 1/4 per cent uranium or 3/4 per cent molybdenum. The average power consumption in all cases was practically the same, so that this factor need not be introduced in comparisons which may be made on the basis of endurance of the tools.

4 Modification in test conditions, including small changes in tool angles but principally changes in cutting speed, more markedly affected the performance of steels containing cobalt or special elements such as uranium or molybdenum than that of the basic types (plain chromium-tungsten-vanadium steels).

5 The relatively poor endurance of the high-tungsten steels under severe working conditions was not observed in more moderate tests which were made on the same test log with equal cutting speed and depth of cut but with reduced feed, and in which the frictional temperatures produced were not so high. Also in these latter tests the performance of the cobalt steels was better than that of either the low- or high-tungsten steels.

6 Hardness determinations and examination of fractures indicate that the various types of commercial high-speed steel show differences in behavior under heat treatment and in physical properties which probably are of importance under moderate working conditions, and might counterbalance slight advantages in performance. (Abstract of *Technologic Paper of the Bureau of Standards*, No. 228, *e*)

Solders for Aluminum. All metals or combinations of metals used for aluminum soldering are electrolytically electropositive to aluminum. A soldered joint is therefore rapidly attacked when exposed to moisture and disintegrated. There is no solder for aluminum of which this is not true.

Joints should therefore never be made by soldering unless they are to be protected against corrosion by a paint or varnish, or unless they are quite heavy, such as repairs in castings, where corrosion and disintegration of the joint near the exposed surface would be of little consequence.

Solders are best applied without a flux or by using paraffin as a flux, after preliminary cleaning and tinning of the surfaces to be soldered. The composition of the solder may be varied within wide limits. It should consist of a tin base with addition of zinc or of both zinc and aluminum, the chief function of which is to produce a semi-fluid mixture within the range of soldering temperatures.

Suggested Ranges of Composition

Tin-Zinc Solders:	
Tin	remainder
Zinc, per cent	15-50
Tin-Zinc-Aluminum Solders:	
Tin	remainder
Zinc, per cent	8-15
Aluminum, per cent	5-12

The higher the temperature at which the "tinning" is done, the better the adhesion of the tinned layer. By using the higher values of the recommended zinc and aluminum percentages given above, the solder will be too stiff at lower temperature to solder readily and the workman will be obliged to use a higher temperature, thus securing a better joint. A perfect union between solder and aluminum is very difficult to obtain.

The joint between previously tinned surfaces may be made by ordinary methods and with ordinary soft solder. Only the "tinning" mixture need be special for aluminum.

There is no reason why a good solder for aluminum need be brittle as several commercial varieties are, and it is very undesirable that it should be.

The tensile strength of a good aluminum solder is about 7000 lb. per sq. in.; those with higher tensile strength have, in general, their temperature of complete liquidation too high for soldering purposes. The strength of a joint depends upon the type and upon the workmanship. Much dependence should not be placed on the strength of a joint. (*Circular of the Bureau of Standards*, no. 78, Mar. 20, 1923, 14 pp., 7 figs., *dp*)

Some Tests of Steel Wire Rope on Sheaves, Edward Skillman. Tests on wire ropes on sheaves, to determine their strength under static load, were made on sizes 5/8, 3/4, 7/8, 1 and 1 1/4 in. in diameter. They were all of 6-strand, 19-wire construction, made from "plow" steel.

It was found that the strength was less than that of the straight rope having socketed ends. Considering the strength of the straight rope as unity, the strength of 5/8-in. rope on 10-in. sheaves was 87.4 per cent and on 18-in. sheaves 95.3 per cent, while 1 1/4-in. rope had a strength of 75.8 per cent on 10-in. sheaves and 84.7 per cent on 18-in. sheaves. The other sizes had corresponding values.

Tensile tests of wires from the ropes showed that the wires had the high strength of 230,000 lb. per sq. in., an elongation of 2 per cent, and a reduction of area of about 46 per cent. The strength was practically the same for all series of the wires.

The strength of the straight ropes followed closely the equation $S = 83{,}000\ d^2$, in which S is the strength in pounds and d the diameter of the rope in inches.

One worn rope which was tested showed a surprisingly high strength when its condition is considered.

A point of inflection in the load diagrams was found at from 56 to 65 per cent of the ultimate load, above which the elongations increased rapidly.

A wire rope under tensile load undergoes considerable elongation and reduction of diameter. The total elongation near the ultimate was about 2.5 per cent after repeated loads.

The modulus of elasticity of steel wire rope may be assumed to be about 8,500,000 lb. per sq. in. for new rope loaded a number of times to one-fifth its ultimate strength.

Some conclusions are drawn upon the effect of heavy loads in squeezing lubricant out of the core of the rope and the wear which follows. (Abstract of *Technologic Paper of the Bureau of Standards*, No. 229, *c*)

FUELS AND FIRING

THE UTILIZATION OF LIGNITE, Prof. Bancroft Gore. A review of the fuel situation in South Dakota, showing the necessity of substituting lignite to replace costly eastern coals. An account is given of experiments made at the Mining Experiment Station in burning lignite in dust form, both dried and undried, to determine the best combustion conditions. The use of unit pulverizers for central heating stations, small power plants, laundries, etc., is advocated and illustrations of several types adapted for this work are presented. The expediency of upgrading lignite at the mine by crushing, followed by drying and removal of dust on impact screens, is emphasized and shown to be an important factor in adapting this fuel for both domestic and industrial purposes.

The lignite received at the Mining Experiment Station of the State School of Mines at Rapid City, South Dakota, from the State Mine, showed a B.t.u. content varying from 7312 as received to 10,744 on a dry basis. It has a high water content and a tendency to break down into fine particles and even powder on air drying. It is softer than any other type of coal. Its main impurity is water.

As regards burning lignite as dust, it is claimed that it is an almost ideal substance to start with as it pulverizes easily and is high in volatile matter. It is interesting to note that as found accidentally by one investigator, lignite coal with as high as 17 per cent moisture was readily pulverized and burned in dust form.

As regards the cost of drying lignite at the mine, data are presented from an estimate prepared by the Ruggles-Coles Engineering Co., who claim that the total cost per short ton of dry coal at the mine is 25.5 cents.

One of the features of the experiments made at the Mining Experiment Station was that after the furnace had been brought to a high heat it was fed with undried lignite having a moisture content of 31.93 per cent. The feed was increased to provide the same quantity of actual combustible matter. The results were so satisfactory that subsequent tests were made on the undried crushed coal, with the exception of special tests or intervals of tests where the highest possible temperature was sought. So far as the author is aware, this is the first record of burning in dust form crude lignite slack containing the original moisture content as received.

The article contains interesting data on the velocity of dust jet carburetion and, in particular, on the dust firing of wet lignite. (*The Black Hills Engineer*, vol. 11, no. 2, pp. 85–126, 24 figs., *cp.A*)

STOKING ANTHRACITE CULM AND GASHOUSE TAR, Joseph Harrington, Mem. A.S.M.E. Description of the installation at the plant of the Consolidated Gas and Electric Co., Long Branch, N. J., for burning a mixture of anthracite culm and liquid tar from gas producers on forced-draft chain-grate stokers without any modification of the furnaces.

The furnace had a total furnace volume of 7.7 cu. ft. per sq. ft. of grate area, and 0.25 cu. ft. per sq. ft. of heating surface. It was of conventional design, and with bituminous coal was smokeless and admitted of ratings up to 250 per cent without destructive temeratures.

The material used accumulated as waste in such quantities as to become a nuisance. With the installation described here it proved to be feasible to use it as a fuel with loads up to 225 per cent of rating, it being possible even with this fuel to carry the loads well over the peak and still have a fair margin to spare.

The material initially had the appearance of a load of asphalt and sand such as is used for the surfacing of macadam roadways. Stepping on this material would pack it into a soggy mass, and precautions had to be taken to prevent such consolidation.

Ready surface ignition was anticipated, but what would happen thereafter could not be predicted. It was feared that the tar would be driven down by the heat of the fire into a more liquid state and render the lower layers of the fuel bed so dense that no air could pass up through. This proved, however, to be wrong. A strong pressure was maintained in the front compartment for the purpose of overcoming any such tendency, and with apparent success, since the mixture ignited with readiness right up to the gate and combustion proceeded with great density until the fuel had progressed approximately one-half the length of the grate. At this point apparently all the tar was burned out, leaving a porous bed of fine anthracite of uniform texture which burned much as any anthracite fire burns. In other words, there were short tongues of flame shooting up through the fuel, a volume of tran-parent monoxide gas at the surface burning to a complete CO_2 product in the upper part of the furnace. Smokeless combustion resulted, and in due course the anthracite culm had all burned down to a perfect ash.

Draft in the furnace was maintained as usual at a point near neutrality. The pressures in the stoker compartments, of which, in this instance there are four, were maintained much as usual with anthracite fuel, except that care was taken to keep the front compartment under full pressure, which, in this instance, averaged about two inches. The second compartment, where the most active combustion took place, was maintained under high pressure, although of slightly less degree, and the third compartment stepped down to perhaps half an inch. The fourth compartment was cut down sometimes to zero, and sometimes to a quarter of an inch according to the appearance or disappearance of fuel over the compartment. (*Power*, vol. 57, no. 14, Apr. 3, 1923, pp. 523–524, 3 figs., *d*)

HANDLING OF MATERIALS

COAL HANDLING BY SUCTION AT THE BRIMSDOWN POWER STATION OF THE NORTH METROPOLITAN ELECTRIC POWER SUPPLY COMPANY. The pneumatic system described is designed to perform three distinct handling operations by means of the one receiver and vacuum pump.

Coal can be discharged from barges lying in an arm of the canal alongside the station at the rate of 50 tons per hour, or, by means of a simple linking up of piping, can be taken from the dumps and conveyed to the bunkers. Further, provision has been made for withdrawing coal from a hopper below a railway track, and this will be put into operation as soon as the siding is completed.

The greatest distance which the coal is taken by the pneumatic plant from the dumps to the coal bunkers is approximately 350 ft., and from the canal arm to the nearest point of the bunkers is 115 ft. The fuel dealt with is usually washed small coal up to $1\frac{1}{2}$ in., but at times rough slack is also handled.

The coal lifted by the intake pipes is delivered into a receiver which discharges through an oscillating tippler to an automatic weigher, whence the coal is delivered to the belt conveyor arranged with a traveling throw-off carriage for feeding the overhead bunkers. The air from the receiver passes through a high-vacuum-type textile-sleeve suction filter which collects the dust, after which the air is run direct into the pump.

The article describes the installation in considerable detail. The pump is of a design (Simon) in which the valves are situated around the outside of the cylinder head, the cylinder being divided into two parts, the inner liner and the outer casing, one side of which is used for exhaust and the other for suction. The piston is fitted with rings having a special system of dry lubrication which has been found most suitable for this class of work; all of the moving parts of the pump are fitted with sight-feed lubricators.

In a recent test of the plant the average capacity during barge discharging, including all trimmings, was over 50 tons per hour, with a maximum rate of 56 tons per hour. (*Iron and Coal Trades Review* vol. 106, no. 2873, Mar. 23, 1923, pp. 426–427, 5 figs. *d*)

INTERNAL-COMBUSTION ENGINEERING

Internal-Combustion Engineering Characteristics of the Vertical Eight, P. M. Heldt. New developments in eight-in-line engines probably will take place in the United States within a few months. The author discusses this type with particular reference to questions of torque, balance, and crankshaft design.

As regard the latter, the author indicates two basic rules for the design of crankshafts for eight-cylinder vertical engines and works out a number of designs that will give equally spaced explosions and no rocking couple, and then proceeds to the discussion of the various designs from the point of view of ease of manufacture. He shows mathematically that in a straight-line eight-cylinder engine the inertia forces are balanced out. Therefore, as far as balance of the reciprocating parts is concerned the eight-cylinder vertical engine is equal to the six-cylinder vertical and twelve-cylinder V-type, and superior to the eight-cylinder V-engine. (*Automotive Industries*, vol. 48, no. 15, Apr. 12, 1923, pp. 817–820, 10 figs., *cg*)

MACHINE PARTS

Roller Bearings on Railroad Cars

The Stafford Roller Bearing for Railway Cars. Description of a bearing which has been in successful operation for a number of months on several cars of the Michigan Central Railroad. It has been applied in a six-wheeled truck running under an American Railway Express car and also to an 80,000-lb.-capacity box car and a flat and gondola car of the same capacity. It is

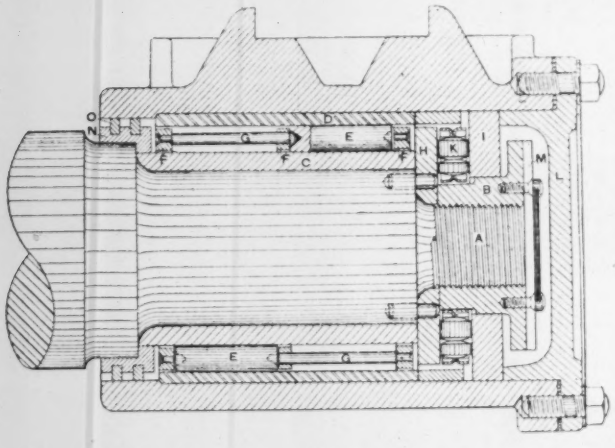

Fig. 2 Vertical Section of Stafford Roller Bearing

stated that these cars traveled a total of 8375 miles after the bearings had been applied. Practically no repairs had to be made to any of these bearings.

The principal claim made for the bearing is the great reduction in resistance effected by its use. While no dynamometer tests have yet been made with cars equipped with this bearing, there is one rough test that may be used to obtain an approximate idea of its possibilities. The flat car already alluded to was loaded with axles until the gross weight amounted to 122,600 lb. and one man was able to push this car on a level track.

The construction of the bearing in its essential parts is shown in Fig. 2. Essentially it consists of a set of horizontal rollers held in a cage to take the vertical load and another set held in another cage to take the end thrust of the axle.

The axle is turned with the ordinary dust-guard seat and journal bearing, the latter having a very generous fillet at the inner end. At the outer end, however, instead of the usual collar there is a projection *A*, which is threaded to take the adjusting nut *B*. In distinction from other roller bearings that have been tried, the turned surface of the axle journal is not used as a raceway for the rollers, but is protected by an inner bushing *C* which is made of high-carbon, high-chrome special roller-bearing steel which is ground and polished on both sides and then pressed on to the journal with a pressure of 4 tons.

The journal box is made to fit the ordinary truck pedestals, whether for trucks having those of the regulation pattern for passenger cars or merely bolts as in the diamond type of freight truck. Its interior, however, is bored to a circular form to meet the requirements of the roller bearing. Like the axle it is provided with a raceway in the form of an outer bushing *D*, which is of the same material as that used on the axle; and is ground and polished on both surfaces and pressed into place with a pressure of 12 tons.

It is between these two bushings that the rollers *E* work. These rollers are held in the cage *F* which is formed of three rings held together by the spacing rivets *G*. These rivets, like the rollers, are staggered in the two sections of the cage, as will be clearly seen in the reproduction of the photograph of this part assembled. The rollers themselves are held in place on 60-deg. centers on trunnions which set into corresponding 70-deg. centers cut in the ends of the rollers. This allows a clearance of 10 deg. for lubrication and also prevents any friction between the trunnions and the counterbore in the ends of the rollers, which latter is $\frac{1}{4}$ in. deep. The remaining part of the rollers is solid.

The end thrust is taken by two plates *H* and *I* with the rollers *K* between them. The plate *H* is provided with dowel pins that fit into the axle by which the two are made to turn together. The inner thrust bearing plate *H* is held in place by the adjusting nut *B* which is screwed tightly against it. The outer thrust bearing plate *I* is held in place by the inside diameter of the journal box, into which it is fitted, there being a clearance between it and the adjusting screw on the inside. It (*I*) is held up against the rollers *K* by an inwardly projecting ring cast solid with the box cover *L*. This journal-box cover is so adjusted that the pressure which it exerts through the outer thrust bearing plate against the end-thrust bearing rollers is neither too heavy nor too light. In short, these parts are so manufactured that the pressure against the thrust-bearing assembly or parts is neither too light nor too heavy.

The adjusting nut *B* is locked by the locking bar *M* which fits in the slot in the nut that can be seen in the reproduction of the photograph, and in a corresponding slot in the end of the axle. The locking bar is itself held in place by two tap bolts that are screwed in to the adjusting nut and are prevented from turning by running a wire through small holes in their heads and tying them together. (*Railway and Locomotive Engineering*, vol. 36, no. 4, Apr., 1923, pp. 102–104, 4 figs., *d*)

The Process of Gear Grinding and a Discussion of Tooth Form. Glenn Muffly. The author claims that ground gears are more durable, probably because they cause less vibration. He also contends that grinding is justified on the cost basis because fewer tear-downs are required and no finishing cut need to be taken in machining.

According to the author, it is now possible to make gear teeth so accurate that it is necessary to consider the deflections under load and so form the tooth as to compensate for even this minute deflection if the maximum silence is to be desired. He also calls attention to the need for accuracy from tooth to tooth, that is, of having each tooth identical in size and contour. There is a possibility of gears being accurate when measured for perhaps one-half the circumference of the gear, but when the measurements from tooth to tooth are considered, the gear is sometimes very inaccurate. This would result in a noisy installation, although by some methods of checking the gears would appear to be exceptionally good.

Looking ahead at the possibilities which may be realized through gear grinding, the author points out that if real quietness can be secured, in the transmission gears, for instance, there might well be a tendency toward overgeared four-speed gear sets. With traffic conditions as they now exist in large cities there is more gear changing, and if quiet gears can be secured it will be possible to narrow the engine speed range and consequently increase the economy of the vehicle. He cites the Citroën car which with a four-speed gear box is reported to have obtained mileages as high as 40 per gal.

Another possible effect of accurately ground gears is the return from helical to straight-tooth spur gears for timing purposes.

The grinding time per tooth can be very quickly calculated. As an example, on a 15-tooth gear taking one cut per tooth the

time averages 14.4 sec. per tooth; on a 21-tooth gear, 9.6 sec., and on a 29-tooth gear, 8.4 sec. These figures refer to 6–8 pitch gears.

The grinding process employed is a wet grinding, hence the heat generated does not draw the gear material.

In the case of one type of gear set it has been found that after 38,850 teeth had been ground on both sides, with two cuts to each side, the cost was $1.75 per gear set.

It makes little difference how close the center distances are held, but the shafts must be parallel. It must be remembered that shafts are not necessarily parallel even when the distance between them at each end is exactly the same.

The stock left for grinding after the rough cut on the gear averages from 0.002 to 0.003 in. on 8–10 pitch gears.

It is not advisable to grind both sides of the gear at once as it brings in too many factors which must be kept synchronized. The maximum variation for backlash in these ground gears is 0.00025 in. (Paper read before the Detroit Section of the Society of Automotive Engineers in April, 1923. Abstracted through *Automotive Industries*, vol. 48, no. 15, Apr. 12, 1923, p. 809, *pg*)

SIX KINDS OF RIVETED JOINTS. According to E. E. Rohrer, of the Coatesville Boiler Works, there are in general six types of riveted joints. First, the lapped and single-riveted seam is almost entirely used for storage-tank work. The efficiency of this type of seam is approximately 50 per cent. Second, the lapped and staggered double-riveted seam, used where medium pressure may be required. The rivets in this type of seam usually have about 1 in. greater pitch than those in the single-riveted seam. This type of joint has an efficiency of about 70 per cent. Third, the lapped and triple-riveted seam, which is comparatively seldom used. Fourth, the butt-strapped double-riveted seam (the butt-strap seams here mentioned have inside and outside butt straps) has an efficiency of about 82 per cent. Fifth, the butt-strapped triple-riveted seam, having an efficiency of about 87 per cent. Sixth, the butt-strapped quadruple-riveted, having an efficiency of about 93 per cent. These latter two are used on larger diameters and for higher pressures. (*Chemical and Metallurgical Engineering*, vol. 28, no. 15, Apr. 16, 1923, p. 679, *g*)

POWER OF WORM GEARING, Arnold A. Arnold. The author discusses the various formulas for the power which worm and worm-wheel gearing will transmit, and in this connection the formulas derived from Bach and Roser's experiments published in the *Zeitschrift des Vereines deutscher Ingenieure*, Feb. 14, 1903; Unwin's formula (Machine Design, vol. 1); and those in Oberg's Spiral and Worm Gearing.

These formulas, the author claims, are not quite suitable for ready calculations as they involve the use of logarithms. He therefore gives four diagrams showing the relation between the horsepower transmitted, the pitch of the worm threads or worm-wheel teeth, the maximum permissible pitch-circle diameter of the worm, and the revolutions per minute of the worm, all these diagrams being based on the formulas referred to above. These diagrams apply only to single, double, treble and quadruple worm threads within certain limits of revolutions. (*Mechanical World*, vol. 73, no. 1890, Mar. 23, 1923, pp. 184–186, 4 figs., *g*)

MACHINE SHOP (See also Engineering Materials)

Experimental Machine Building—Pictorial Assemblies

CONTROLLING COSTS IN BUILDING EXPERIMENTAL MACHINES, Fred H. Colvin. The second article of a series, showing how tools are to be decided upon and the operation times set. Among other things, the article describes so-called pictorial assemblies, the pictures being sketches in perspective which show the design of the piece, so that there can be no mistake as to what it looks like. This is particularly useful when it comes to assembly work. An example is given in Fig. 3 which shows a unit assembly of a controller. This consists of seven sub-assemblies, one of each being required for the complete unit. Each sub-assembly is numbered and full details of it can be found under that number. Each of the sub-assemblies may be represented by a special pictorial assembly, which, in its turn may include minor sub-assemblies, as is, for example, the case with the sub-assembly No. 3192.

The assembly sheets may be, however, a good deal more complicated than that shown in Fig. 3. For example, one of the illustrations in the original article shows a complete assembly of a separator involving a number of sub-assemblies, and finally one

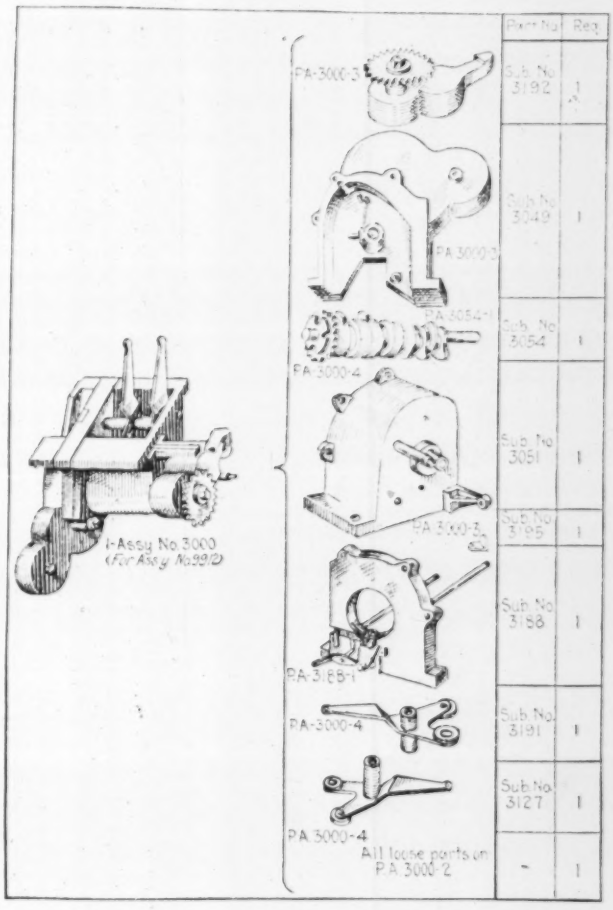

FIG. 3 PICTORIAL ASSEMBLY OF CONTROLLER UNIT

assembly which shows a complete machine comprising five separators, a carrying unit, loader connections, etc.

Such assembly drawings are valuable in that they leave little room for error and make it possible for mechanics to assemble a machine without difficulty, even if they are not especially familiar with the machine. (*American Machinist*, vol. 58, no. 14, Apr. 5, 1923, pp. 503–507, figs. 3–14, *dp*)

MANAGEMENT ENGINEERING (See Machine Shop)

METALLURGY (See Engineering Materials)

MOTOR-CAR ENGINEERING (See also Internal-Combustion Engineering)

LARGE-SECTION TIRES ON PASSENGER MOTOR CARS, Herbert Chase. Important results are expected from the development of a so-called "balloon" tire, which is essentially a tire of the same outside diameter as those in use at present but of much larger section and fewer plies. This is accomplished by using a smaller rim diameter. For example, in place of a 33 by 5-in. 8-ply cord tire on a 32 by 4½-in. rim 23 in. in diameter, is used a 34 by 7-in. 4-ply tire on a 29 by 4½-in. rim 20 in. in diameter. Instead of a pressure of 65 lb. the new tire operates at 25 lb. inflation pressure.

The results are said to be very remarkable. In the first place, road inequalities are transmitted to a far lesser extent than with ordinary tires. The brakes become more effective, and slipping and skidding on wet pavements are largely eliminated. There are not enough data available to show the comparative wearing qualities of the conventional type of cord tire and the newer type

which is also of cord construction. The use of the new-type tire is claimed to result in saving in unsprung weight and, consequently, in a secondary saving by way of lesser impact on the road surface.

The new large-section tires with their lower inflation pressure absorb a much larger proportion of the shock due to the road inequalities. There is less fatigue to the operator and also less vibration transmitted to the chassis, which makes the cars quieter in operation. It is claimed that the use of new tires increases the maximum speed of the car and lowers its fuel consumption. On the other hand, however, it is pointed out that when the car is traveling at high speed there is an increased danger of accident due to blowout because of the thinner wall of the tire.

Among the disadvantages may be mentioned the necessity of changing the design of the chassis, for approximately the same diameter of large-section tire will have less side clearance in relation to body and chassis parts. In some cases this might require a decrease in the width of the rear seat and a decrease in the width of the chassis at the front in order to enable the use of the same steering lock and to maintain the same turning radius.

It is said that a number of prominent car manufacturers are said to be seriously considering the adoption of 34 by 7-in. or 32 by 6-in. tires as standard equipment in the near future.

The article is accompanied by expressions of opinion from several car and parts manufacturers, as well as from various tire companies who have been doing work along this line. (*Automotive Industries*, vol. 48, no. 15, Apr. 12, 1923, pp. 812–816, *dg*)

POWER-PLANT ENGINEERING

Solar Power Plant—Design and Costs

The Berland-Caufourier Solar Power Plant, P. Caufourier. There have been many attempts to utilize solar heat for power generation, of which the author mentions and briefly describes the Mouchot, Tellier, and Shuman projects, the last being the only one to be applied for actual work. (See Journal A.S.M.E., vol. 37, 1915, p. 661.)

The present installation is a combination of the Caufourier self-vaporizer for generation of steam from water at temperatures of 50 to 75 deg. cent. and the Berland system of mirrors. The Caufourier self-vaporizer was initially designed for purposes of power generation from natural hot waters and was described in Mechanical Engineering, vol. 43, no. 3, March, 1921, pp. 200–201.

The Berland solar receiver, as the apparatus is called, is shown in Fig. 4. It is a mirror shaped as a parabolic cylinder—similar to the mirrors in the Shuman Egyptian installation, yet differing therefrom in certain essential points. The axis instead of being horizontal is parallel to the axis of the earth and hence in the Sahara has an inclination of 25 to 30 deg. to the horizontal. Under these conditions the solar rays are normal to this axis at the equinoctials and even at solstices their inclination does not exceed 23 deg. The apparatus is therefore better capable of receiving the insolation (solar radiation) than if it had a horizontal axis, and furthermore the inclination to the horizontal favors a natural circulation of the water. The angle of inclination of the solar rays remains constant throughout the day period, provided the mirror has a movement of uniform rotation, which may be automatic. To effect this the mirror is mounted in a series of large circular tracks traveling on rollers, as shown in Fig. 4, where E is the driving gear, G the rollers, C the rolling track, M the parabolic metal mirror, T the boiler tube—which may be of copper or aluminum with a black exterior face, and V a glass sleeve. The frame supporting the mirror is not shown. The boiler tube T is enclosed in one or two glass cylinders, the purpose of which is to prevent dark heat radiating from the tube and thus to reduce the heat losses therefrom. This particular feature was first proposed by Mouchot. The air between these glass cylinders and the boiler tube is partly exhausted in order to reduce convection losses.

According to calculations made by the Swedish scientist Svante Arrhenius, 1 sq. m. (10.764 sq. ft.) of the great circle of the terrestrial sphere receives 25 calories of solar heat per minute. Taking into account the inclination of the solar rays and atmospheric absorption, 1 sq. m. of the mirror will receive from 8 to 9 cal. per min., and as the efficiency of the mirror is of the order of 60 per cent as shown by tests made on the Cairo installation, the water in the boiler tube is capable of absorbing, roughly, 300 cal. per hr. per sq. m. of mirror surface.

On the other hand, if we assume that the water is heated to 90 deg. cent. in the solar receivers and reduced to 80 deg. in the self-vaporizers, the production of steam will equal 18 kg. per cu. m., equivalent to 3.18 i.hp., or 2.5 hp. on the turbine shaft, figuring the condenser at 25 deg. cent. The author further shows that the mirror surface would have to be 18 sq. m. per hp.

The solar power plant illustrated in Fig. 5, will therefore comprise—

1 A sufficient number of Berland solar receivers

2 One or more intermediary reservoirs

3 A sufficient number of self-vaporizer steam generators

4 A water circulation pump and a vacuum pump

5 A superheater, which is essential for drying the steam and at the same time increasing its temperature and hence the Carnot efficiency. A superheat of 35 to 40 deg. cent. would appear to be sufficient. This is the only part of the apparatus that will consume fuel

6 A reciprocating steam engine, or still better, a steam turbine

7 A condenser with its auxiliary equipment.

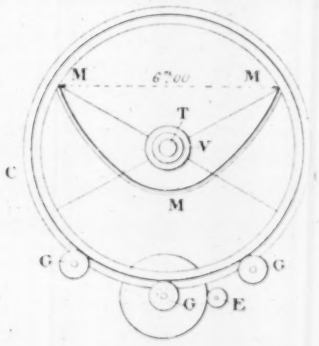

Fig. 4 Berland Solar Receiver

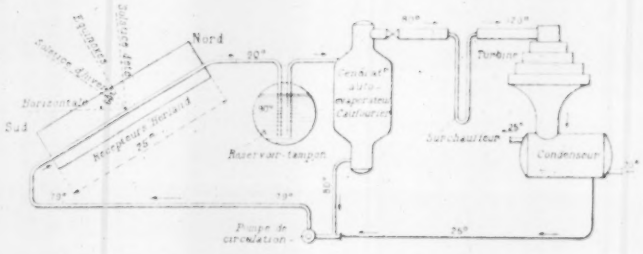

Fig. 5 Diagram of a Solar Power Plant of the Berland-Caufourier Type

(*Sud* = south; *Solstice d'hiver* = winter solstice; *Equinoxes* = equinoctials; *Solstice d'été* = summer solstice; *Nord* = north; *Récepteurs Berland* = Berland solar receivers; *Réservoir tampon* = intermediary reservoir; *Générateur auto-évaporateur Caufourier* = Caufourier self-vaporizer steam generator; *Surchauffeur* = superheater; *Pompe de circulation* = circulating pump; *Condenseur* = condenser)

In the climate of southern Algeria the average time the installation is capable of operating is 10 hr. per day, 330 to 340 days per year, and it is proposed to use the power generated primarily for pumping water for irrigation purposes and also for generating comparatively small amounts of power for lighting and industrial power.

In order to deliver power continuously it will be necessary to have a number of solar receivers approximately double the power of the evaporators, and an intermediary reservoir of sufficient dimensions and properly protected against heat losses.

The condensers will use the irrigation water, and where this is not available shallow pools may be used. A fairly complete project of the application of this type of power plant has been worked out for the Touggourt oasis, which is of interest in that it demonstrates the conditions under which a power plant of this character may pay. The Touggourt oasis has a population of 12,000, and a flora comprising 350,000 palm trees. It was initially irrigated by 200 artesian wells, which in 1861 had an output of 1000 liters (265 gal.) per sec. The boring of new wells, however, has depressed the subsoil water level and made it necessary to go to much lower levels in order to obtain new sources of water, and even these have been gradually failing.

The project calls for a solar power plant with a mirror area of 2400 sq. m. (25,833 sq. ft.) giving an output of 100 kw. with an insolation of 7 cal. per sq. m. (10.764 sq. ft.). The power output per year will be 300,000 kw-hr., consumed as follows:

In the power plant itself	30,000
Lighting of villages	30,000
Small industries	20,000
Ice manufacture	10,000
Irrigation pumping	210,000
Total kilowatt-hours	300,000

It is estimated that the cost of construction will be 600,000 fr. ($42,000) of which 150,000 fr. ($10,500) will be for the mirror plant. The income and expenditures are estimated as follows:

Expenditures (in francs = 7 cents)		
General expenses		3,000
Personnel	Manager	15,000
	Electrician	9,000
	Four native workmen	7,000
Lubrication, waste, etc., 0.01 fr. per kw-hr.		3,000
Superheater service, 0.200 kg. (0.44 lb.) of coal per kw-hr.		20,000
Maintenance and repairs		20,000[2]
Amortization at the rate of 6 per cent in 15 yr.		60,000
Interest, etc.		115,000
Total		252,000
Receipts		
Lighting, 30,000 kw-hr. at 1.50 fr.		45,000
Petty industries, 20,000 kw-hr. at 1.00 fr.		20,000
Ice, 100 tons at 200 fr.		20,000
Distilled water, 360 tons at 75 fr.		27,000
Irrigation pumping,[1] 200,000 kw-hr. at 0.70 fr.		140,000
Total		252,000

In the above plans no mention is made of the depreciation of the distribution system, the item "Interest" being sufficient to take care of this.

The item "Distilled water" corresponds to a daily consumption of 1000 liters (265 gal.) which is double the present consumption, but it is to be sold at a price of 0.075 fr. per liter as compared with the present price of 0.20 fr. Water from the wells contains too much magnesia salts to be fit for drinking. (*Génie Civil*, vol. 82, no. 14, Apr. 7, 1923, pp. 327–329, *d*)

Water-Tube Boiler Troubles

CONSTRUCTIONAL DEFECTS IN WATER-TUBE BOILERS, R. Schirmer. This paper calls attention to the fact that of later there have been increasingly frequent reports of trouble with water-tube boilers, in particular ruptures of the boiler walls, and that the causes of these troubles are not yet as clear as they should be.

The author believes that many of these accidents have been due to the constantly increasing specific loads imposed on the boilers, as a result of which the boiler parts do not take up the heat supplied to them fast enough and distribute it uniformly enough, which brings about stresses in the material. To this kind of damage are particularly exposed boilers which have been at first operated at comparatively light loads and from which a much higher output had been demanded later. In some cases, in order to obtain this higher output larger grates have been installed in the expectation that the boiler would deliver the greater output as it had worked satisfactorily in the past. Of course this does not always happen.

H. Schonger, in a recent German publication, has called attention to the fact that cracks in boilers operating in central stations are particularly frequent in the header flanges and end plates of water-tube boilers. All conditions, however, go to show that it is not the defective manufacture of the parts but the circumstances of their operation that are the cause of trouble. It is pointed out particularly in this connection that such flange ruptures do not occur in other boiler systems or in old water-tube boilers, possibly because these latter have operated at only a fraction of their present specific loads. It would therefore appear that the accidents in boiler operation are due at least in part to the increasing loads which have been demanded from boilers since the introduction of the Stirling type of generator. There has been of late a sort of competition between the Stirling and the straight-tube types of boiler, each attempting to surpass the other either in specific output or in the reduction of space for a given output. The Stirling type is well adapted for this kind of competition, whereas the straight-tube boiler has been made to perform at the enhanced rate without a thorough alteration of its design, which is unfortunate, because a straight-tube boiler appears to be unsuited by its construction for the rapid equalization of thermal expansion of the parts. As a result there have been numerous breakages of parts which can be directly ascribed to stresses of thermal origin.

It is stated in the report of H. Schonger, referred to above, that the flange cracks reach their greatest depth at the lowest part of the end plate, and in extending toward the water line on both sides gradually lose in depth. The same thing has been observed on the lower drums of a large Stirling-type boiler. These drums, it may be stated, were in this instance made not of a single shell plate but of three rings.

Figs. 6 and 7 show these lower drums. All such boilers have two boiler drums connected by short curved tubes, the water circulating in the direction indicated by the arrows. It is usually

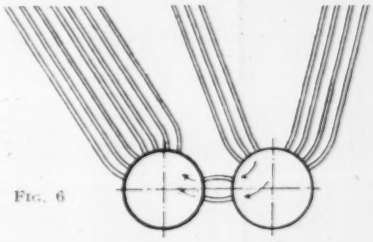

FIG. 6

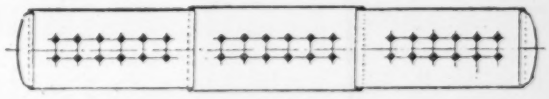

FIG. 7

FIGS. 6 AND 7 CONSTRUCTION OF LOWER DRUMS OF A BOILER WHERE LEAKS DUE TO UNEQUAL HEATING APPEAR

FIG. 8

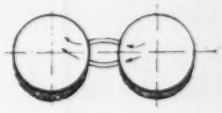

FIG. 9

FIG. 8 DIAGRAMMATIC REPRESENTATION OF DISTRIBUTION OF LEAKS IN THE DRUMS OF BOILER SHOWN IN FIGS. 6 AND 7.

FIG. 9 DIAGRAMMATIC REPRESENTATION OF WATER CIRCULATION IN THE DRUMS OF BOILER SHOWN IN FIGS. 6 AND 7.

assumed that the total drum water content is free to circulate at a uniform rate and therefore that there are no dead spaces in the lower drum. While firing up this boiler, however, leaks appeared at the circular seams as soon as the temperature of the water in the upper drum approached the boiling point. When the steam pressure increased the water spurted through the seams in jets, the interesting part about it being that this occurred only on the lower part of the two lower drums, while the upper parts of the same drums have never shown any lack of watertightness. Moreover the leaks increased with the approach to the middle plane of the drums as shown diagrammatically in Fig. 9, but ceased entirely at the level of the lower connecting tube. No matter how slowly and carefully the boiler was heated up, it proved to be impossible to prevent these leaks, and even after the upper drum began to deliver steam, cold water could be obtained from the lower drum by opening the bottom cock. It was, however, possible to combat this source of trouble by letting off from time to time the water from the lower drums during the heating up of the boiler, this operation being repeated until the water in the lower drum attained a temperature corresponding to the steam pressure, whereupon the danger of leaks disappeared.

There is no doubt that these leaks are caused purely through thermal stresses, which in their turn are due to the imperfect water circulation in the lower drums.

As shown in Fig. 8, there forms in the lower drum a dead layer of cold water at the level below the interconnecting tubes, while the water above this dead layer circulates with the rest of the boiler water. This results in the fact that the upper part of the shell of the lower boiler is heated up faster than the lower part,

[1] Attention is called to the fact that in a previous paragraph the power consumption for irrigation pumping is estimated at 210,000 kw-hr. and no mention made of distilled-water production, possibly because the latter is merely a by-product.

and as the circular rivet seams are not strong enough to withstand the stresses created by this unequal expansion, leaks appear in the drum. It is only after all the cold water from the bottom of the lower drums has been drawn off through the cocks that the two parts of the shell become heated up uniformly and the irregular thermal expansions and consequent leaks disappear.

It is permissible to assume that the rupture of a welded seam in the lower drum in another large Stirling-type boiler may have been due to the same cause. In this case it is well to avoid the use of welded circular seams, or at least when using them to employ reinforcing straps.

From this the author proceeds to a discussion of straight-tube boiler troubles, which he believes may be likewise due to thermal stresses produced by unequal heating. In fact, he believes that the straight-tube boiler is exposed to this kind of trouble in an even greater degree than the Stirling type. Furthermore the lower half of the shell of the upper drum in the straight-tube boiler is exposed to additional stress due to the fact that the tube system expands to a greater degree than the boiler drum located above it. If, therefore, the circular seams of the upper drum lying between the collars of the headers are strong enough to take up these additional stresses, the flanges of the header covers or connecting expanders will be frequently overstressed to such an extent as to produce ruptures. These stresses applied initially to flanges are transmitted to the end plates with all the greater ease the nearer the latter are forced to the connector expanders. Furthermore, since the rear end plates are located closer to this critical connecting place the front end plates are more exposed to the successive stresses, which would explain the greater frequency of cracks and ruptures in these rear end plates.

It would be natural to expect that damage of this kind would occur with particular frequency in boilers which are fired up often rather than in boilers operating continuously. After a boiler has been operated for any length of time the heat throughout becomes equalized to such an extent that the stresses in the material disappear. In central-station practice the boilers have to be cut in and out with comparative frequency. Furthermore, when high peak loads have to be taken care of, extra boilers must be heated up quite frequently and rapidly. Conditions of boiler operation in central stations are therefore such as to be particularly favorable to the formation of cracks and ruptures. On the other hand, of course, boilers should be adapted to take care of conditions in central-station operation rather than that these latter should suffer in their adaptation to boiler limitations. Boilers should be so built that even when fired up in a hurry the heat will distribute itself throughout the boiler in as short a time as possible, not only uniformly but without the production of local stresses even when the load is varied with great rapidity. This requirement can be satisfied only by the establishment of a perfect water circulation of the entire water content, which is far from being the case with the present conventional construction of straight-tube boilers.

From this point of view greater advance has been made in Stirling-type boilers and of late there has been an increasing tendency to provide large connections to the upper drums, the only limit to this tendency lying in the strength of the boiler shell. Larger passages are also provided for the flow of steam between the upper drums.

At the same time it should not be forgotten that all connections between the upper drums may result in hindering the water circulation, as improper dimensioning of such connecting elements may lead to violent variations of the water level, priming, etc. It is because of these difficulties that there is still considerable distrust in many circles with respect to the Stirling-type boiler. (*Die Wärme*, vol. 46, no. 2, Jan. 12, 1923, pp. 15–18, 4 fig. *p*)

RAILROAD ENGINEERING (See also Machine Parts)

New 4000-Hp. Electric Locomotives for the N. & W. Railway, T. C. Wurtz. Description of the design of four locomotives recently ordered by the Norfolk & Western Railway, the particular points of interest being the design of the cab and drivers, and some of the electrical features.

The new unit will consist of two cabs permanently connected to form a locomotive. The equipment in each cab will be identical so that any two cabs can be coupled together back to back to form a locomotive unit.

The cab structure is not supported by springs and sliding bearings as formerly but is fastened rigidly to and is carried by side frames. These latter are massive vanadium-steel castings connected by cross-ties which are also used to support the heavier pieces of electrical apparatus mounted in the cab.

The four pairs of drivers on each cab are single-truck, the former practice having been to have two trucks on two pairs of drivers each connected by a Mallet hinge.

As regards the electrical features, the most interesting is the use of an oil-insulated force-cooled transformer. The oil-insulated type of transformer has been almost universally used in single-phase European electrifications, but up to this time the air-blast transformer was the standard in this country in all trunk-line installations. Cooling of the oil-insulated transformer is accomplished by means of pumping the oil through a force-ventilated radiator.

The service to be performed by these locomotives is unquestionably the most severe to which any electric locomotive has ever been subjected. The traffic consists of heavy-tonnage coal trains of 4200 tons hauled up six miles of 2 per cent grade on a road noted for its curves. The speed of the train up this heavy grade with two locomotives is 14 m.p.h. Acceleration of these heavy trains on a 2 per cent grade with reverse curves is part of the normal operation, and is accomplished with ease. The performance of this type of locomotive has been so remarkable that the operating officials of the railway are enthusiastic in their praise and more than satisfied with their operation, as shown by the recent order for four additional locomotives having 30 per cent greater capacity than those now in operation. (*Railway Review*, vol. 72, no. 15, Apr. 14, 1923, pp. 647–650, 4 figs., *d*)

REFRIGERATION

The Compression Refrigeration Cycle

The Compression Refrigerating Cycle, W. H. Motz. Paper based upon the results of the recent Bureau of Standards experiments on ammonia and what may be termed good operating practice. The author gives numerous interesting charts plotted for the first time from the Bureau of Standards tables and also from actual tests on a refrigerating machine. The paper is not generally suitable for abstracting, but attention may be called to the following.

In the original article a chart is given showing the values of the theoretical volumes of compressor piston displacements for the assumed conditions in the evaporator and condenser. (The amount of ammonia evaporated per minute per ton of refrigeration has been taken for standard conditions as 0.442 lb.)

As regards volumetric efficiencies of a compressor cylinder, they appear to depend generally on a large number of factors. However, in vertical single-acting compressors in which the clearance has been reduced to the minimum and in which valves of large area are used, the principal factor affecting the efficiency of the cylinder is that of the superheating of the vapor during the suction stroke. With respect to the volumetric efficiency due to the superheat of the vapor during the suction stroke, it is said that there are a number of factors which affect the relative magnitude of this efficiency. In consideration of this fact it is practically impossible to determine these efficiencies by mathematical analysis, and they can be determined only by actual tests on actual ammonia-compressor cylinders and should therefore be termed an operating characteristic of the compressor cylinder.

For the purpose of comparison and calculation in this paper the author has used tests made on actual ammonia-compressor cylinders for the purpose of determining the relative magnitude of the efficiency due to superheating. Data taken from the most authoritative tests were plotted on curves, from which, by means of extension and extrapolation, the values of the volumetric efficiencies for the assumed conditions were obtained. The values of the volumetric efficiencies due to superheating, as determined by this means for vertical single acting ammonia compressors, are shown in Fig. 10. These values are the volumetric efficiencies with a factor of safety of approximately 10 per cent. As previously

indicated, these may be termed volumetric efficiencies due to superheating, due to the fact that a very large proportion of the loss of efficiency is due to the superheating effect. The tests on the actual refrigerating machines were conducted by experts after all parts of the system had been put into as nearly perfect mechanical condition as possible, clearance reduced to the minimum, etc. Therefore the values of the volumetric efficiencies may be taken to present primarily the effect of superheating. It is well to

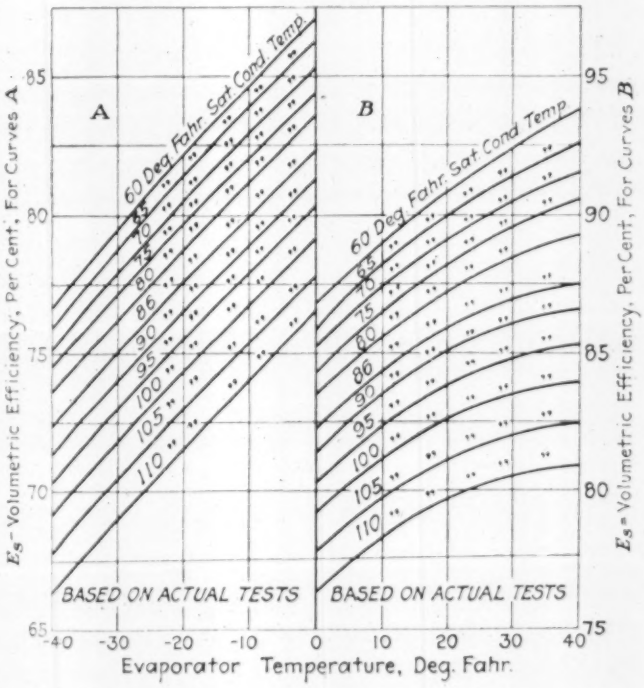
A
B
60 Deg. Fahr. Sat. Cond. Temp.
BASED ON ACTUAL TESTS
BASED ON ACTUAL TESTS
Es = Volumetric Efficiency, Per Cent, For Curves A
Es = Volumetric Efficiency, Per Cent, For Curves B
Evaporator Temperature, Deg. Fahr.

FIG. 10 VOLUMETRIC EFFICIENCIES FOR VERTICAL SINGLE-ACTING COMPRESSORS

point out that it is possible to obtain volumetric efficiencies which are better than those shown by Fig. 10, but that these values may be assumed to represent good practice.

The author next discusses the effect of clearance upon the volumetric efficiency of a compressor cylinder, which may be determined mathematically if the amount of clearance is known, and gives a

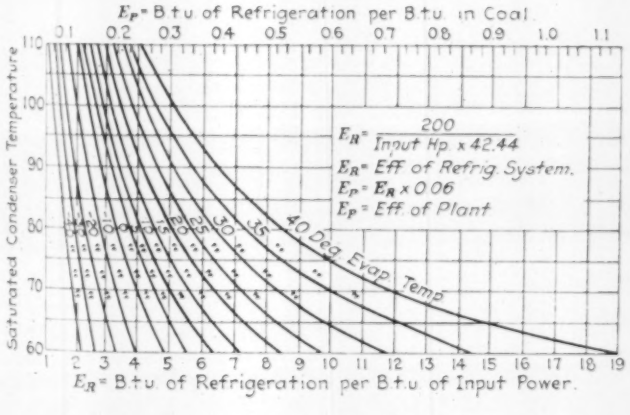
Ep = B.t.u. of Refrigeration per B.t.u. in Coal
Saturated Condenser Temperature
ER = 200 / Input Hp. x 42.44
ER = Eff. of Refrig. System.
Ep = ER x 0.06
Ep = Eff. of Plant
40 Deg. Evap. Temp.
ER = B.t.u. of Refrigeration per B.t.u. of Input Power.

FIG. 11 OVERALL EFFICIENCIES OF REFRIGERATING PLANTS

chart showing the value of factors determining this clearance.

The thermodynamical expression for the volumetric efficiency due to clearance [the formula is given in the original article] involves the exponent n of the characteristic law of compression PV^n = constant. This exponent varies within certain limits as ammonia vapor is not a perfect gas, but the latest data from the Bureau of Standards on the properties of ammonia vapor seem to indicate that the average value of n may be taken to be 1.28, and the author uses this value both to express the volumetric efficiency due to clearance and to determine the total efficiency due to clearance. This latter, on the assumption that the clearance is 3 per cent of the cylinder volume, is found to be 92.56 per cent or a given case.

The true volumetric efficiency of the compressor cylinder is a function of the product of the volumetric efficiency due to superheating and that due to clearance. The mean effective pressure of ammonia in a compressor cylinder is also affected by the amount of clearance.

The second part of the article is devoted to the subject of power and water requirements, and is accompanied by interesting charts.

Among other things, the author establishes in the form of an equation the relationship between the gallons of water required per minute, the heat removed in the condenser, and the temperature range of water, and gives a chart showing the relative amount of water required in gallons per minute per ton of refrigeration for rises of temperature of the water from 4 deg. to 20 deg. for certain assumed operating conditions.

The efficiency or coefficient of performance of refrigerating systems is next discussed and expressed in several ways. The general conclusion at which the author arrives is that the smaller the temperature range the better the performance. In other words, a smaller amount of energy is required to cool a substance a few degrees than is required to cool a part of it through several degrees, such as one-tenth of the substance through ten times as many degrees. For standard conditions the overall efficiency on performance is expressed as a formula. The ratio given may be termed B.t.u. of refrigeration per B.t.u. in the coal. In the original article such ratios of B.t.u. of refrigeration to B.t.u. in coal have been calculated for the assumed operating conditions and are shown in Fig. 11. (Paper presented at the Annual Meeting of The American Society of Refrigerating Engineers, December, 1922, abstracted through *Refrigerating Engineering*, vol. 9, no. 9, March, 1923, pp. 267–274 and 279–280, 12 figs., *pt*)

COMPOSITION, PURIFICATION, AND CERTAIN CONSTANTS OF AMMONIA, E. C. McKelvy and C. S. Taylor. In this paper methods for the testing of commercial ammonia are described and applied to eight standard American brands and three brands of German origin. The results of these analyses indicate that most commercial ammonias contain less than 0.1 per cent of impurities. Previous methods used for the preparation of pure samples are reviewed briefly. Apparatus used for fractional distillations at pressures greater and also less than atmospheric pressure are described.

Emphasis is placed upon the removal of non-condensing gases, and methods of removal and testing are described in detail, together with a method for opening sealed glass containers and testing the contents for non-condensing gases.

Five methods for the preparation of samples are described in detail and the physical measurements made upon each sample indicated. The different preparations are tabulated, together with the analyses and uses.

Ammonia has been prepared which contained, as far as any known test indicated, no organic impurities, less than 1 part in 1,000,000, by volume, of non-condensing gases, and less than 0.003 per cent, by weight, of water.

The following physical properties of pure ammonia were determined: The density of the solid, 0.817 gram per cu. cm. at —79 deg. cent. and 0.836 gram per cu. cm. at —185 deg. cent.; the freezing point, —77.70 deg. cent., and the vapor pressure at that temperature, 45.2 mm. of mercury. (*Scientific Paper of the Bureau of Standards*, no. 465, Mar. 9, 1923, pp. 655–693, 6 figs., *e*)

SPECIAL MACHINERY (See Engineering Materials)

SPECIAL PROCESSES (See Engineering Materials)

CLASSIFICATION OF ARTICLES

Articles appearing in the Survey are classified as *c* comparative; *d* descriptive; *e* experimental; *g* general, *h* historical; *m* mathematical; *p* practical; *s* statistical; *t* theoretical. Articles of especial merit are rated *A* by the reviewer. Opinions expressed are those of the reviewer, not of the Society.

Proposed Code for Care of Power Boilers

Preliminary Report of Sub-Committee of A.S.M.E. Boiler Code Committee on Rules for Care of Steam Boilers and Other Pressure Vessels in Service

THIS Report of the Sub-Committee of the Boiler Code Committee on Code for the Care of Power Boilers is suggestive only and will be proposed for discussion at the Spring Meeting of the Society at Montreal, Que.

The work of this Sub-Committee of the A.S.M.E. Boiler Code Committee has been actively pushed forward during the past year and its report is here presented for public discussion. This report is intended to form a section of the A.S.M.E. Boiler Code, the Sub-Committee which was appointed in 1922 to consummate this work being as follows:

F. M. GIBSON, *Chairman*
E. G. BAILEY
W. G. DIMAN
J. R. GILL
J. W. HAYS
S. F. JETER
W. H. LARKIN, JR.
J. S. SCHUMAKER
H. F. SCOTT
N. STAHL
J. WOLFF

It is the request of the Committee that these proposed rules be fully and freely discussed so that it may be possible for any one to suggest changes before the rules are brought to final form and presented to the Council for approval. Discussions should be mailed to C. W. Obert, Secretary of the Boiler Code Committee, 29 West 39th St., New York, N. Y., in order that they may be considered by the Boiler Code Committee.

A.S.M.E. BOILER CODE

Report on Rules for Care of Steam Boilers in Service

POWER BOILERS

These Rules apply only to steam boilers constructed in compliance with Part I, Section 1, of the A.S.M.E. Boiler Code and for operation at a steam pressure exceeding 15 lb. per sq. in. above atmospheric pressure. These rules do not apply to boilers which are subject to federal inspection and control, including marine boilers, boilers of steam locomotives and other self-propelled railroad apparatus.

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- Excessive Combustion—Damper regulators; fuel-supply regulators
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- Overheating—Lack of water supply; fouled heating surface; excessive combustion; secondary combustion and flaming through; localized heating; damper regulation; insulation
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OVERPRESSURE

INDICATORS

C-1. Steam Gages. Steam gages shall be placed where they will be free from vibration and where they can be conveniently adjusted. They shall be so placed that they will not be subjected to a temperature of less than 40 deg. fahr. or more than 150 deg. fahr. They shall be of such size and so proportioned and marked that the position of the pointer and the graduations can be clearly determined by a person with normal vision standing on the operating floor at any point within a radius of one and one-half times the width of the boiler setting measured from the center of the boiler front. Steam gages on all boilers, where set in battery, shall be practically the same in size and graduation of face.

C-2. Steam gages shall be well lighted at all times. When natural light is used the gage shall be so placed that the rays of light will not cause a reflection upon the glass cover thus obscuring the dial when viewed from the most desirable points of observation. When artificial light is used the light shall fall directly upon the face of the gage. Whatever form of light is used, no light shall fall directly into the eyes of the operators when looking at the gage from the most desirable points of observation.

C-3. Where steam gages are installed with waterleg, compensation shall be made in the gage to neutralize the effect of the water in the gage connections. Where steam gages are placed high above the operating floor, they shall be tilted forward at a sufficient angle (not to exceed 30 deg. with the vertical) to permit a proper view of the dial graduations.

C-4. Piping for steam gages shall be as short as practicable and shall be free from pockets and air traps. When the pipe line is longer than 10 ft., the pipe size shall not be less than $\frac{1}{4}$ in. standard pipe size.

C-5. A steam gage shall be considered tested when it has been compared and made to agree with a test gage or dead-weight testing device, unless compensation for waterleg has been made, in which case an equivalent allowance shall be made in the reading of the test gage or dead-weight testing device. The test gage shall be a reliable gage that is used exclusively for testing gages in service and one that is tested and maintained in agreement with a dead weight testing device.

C-6. Boiler gages shall be tested frequently, at times of external inspection, when boiler is placed in service, and when safety valve is operating and the pressure indicated by the steam gage is not in agreement with the pressure at which the safety valve is set to open.

C-7. A master gage is an auxiliary gage attached to the main header indicating the composite boiler pressure of the whole battery; it is used in the general operation of the plant mainly as a matter of convenience. Master gages shall be tested at least every three months and more frequently when trouble is experienced with boiler compounds, foaming, priming and other feedwater troubles that are apt to cause choking of the gage piping.

C-8. All steam gages shall be within two per cent of error in the range between the working pressure and the pressure of the opening of the safety valve.

C-9. Before a steam gage is tested, it shall be disconnected at the gage union while the piping, cock and siphon are being cleared

by blowing through. A tee with a plug shall be placed between the siphon and the gage for the purpose of connecting the test gage. Care shall be taken not to admit steam directly into the gage, making sure at all times that the siphon is filled with water. In opening the connection to the gage, the operator shall open the cock slowly while holding one hand on the siphon until the gage indicates full boiler pressure; if the temperature of the siphon indicates that steam instead of water is entering the gage, the cock shall be closed until a sufficient amount of water has accumulated in the piping.

C-10. When laying up a boiler, particularly in freezing temperatures, the gage connection shall be drained and the gage shall be disconnected and stored away in a non-freezing room.

C-11. The dial and glass cover of steam gages shall be kept clean at all times. The glass cover joint shall be tight and, whenever the glass is broken, it shall be replaced as soon as possible.

C-12. Water Glasses and Gage Cocks. The valves and connections between the boiler and water column shall be kept free and clear and shall be tested by blowing down the water column, noting the return of water in the glass, and trying the gage cocks until sure of the water. They shall be tested by the responsible operator on the relieving shift before the relieved shift has gone off duty, also after replacing or cleaning the water glass and when a boiler is put in service.

By *shift* is meant a person or group of persons who relieve a person or group of persons in rotation in standing watch or operating a steam generating plant for an allotted time. It is synonymous with watch, vigil, or tour of duty.

C-13. The water glasses and their connections shall be kept free from leaks and no alterations, allowing a flow of water from the piping between the water glass and the boiler, shall be made.

C-14. The outlet end of the discharge pipes from the water columns, water glasses and gage cocks shall be kept open and either in sight or in hearing of the operator while blowing down.

C-15. The water glasses shall be so lighted that the level of the water in the glass can be readily seen from the most desirable points of observation and the light shall be so shaded that it will not shine directly into the eyes of the operator when looking at the glass. The inner and outer surfaces of the water glass shall be kept free from deposits of dirt and the connections of the water glass shall be so arranged that the inner surface of the glass can be cleaned by forcing through the glass a piece of cloth, free from lint and dirt, wound about a smooth piece of wood. Types of gage glasses and guards which prevent the free observation of the glass shall not be used.

C-16. Where automatic alarms for indicating extreme low water level or extreme high water level are used, they shall at all times be kept in good working order but shall not be depended upon in maintaining a proper level of water in the glass. When an automatic alarm sounds and the level of the water is not visible in the glass, the operator shall test the try cocks to determine the water level before manipulating the feed water valves.

C-17. Fusible Plugs. Fusible plugs, if used, shall be kept in good condition and shall not be used for more than one year as provided for in Par. 428 of the Rules for the Construction of Power Boilers. When the boiler is open, the exposed surfaces of the fusible metal shall be scraped clean and bright and the surface of the boiler near the plugs shall be scraped clean. If the fusible metal does not appear sound, the plug shall be renewed. If used plugs are refilled, all of the old filling shall be removed, the surfaces of the shell scraped bright and properly tinned and the plug filled with pure tin as specified in Par. 428 of the Rules for the Construction of Power Boilers. Fusible plugs shall not be refilled with used metal.

Relief Equipment

C-18. Safety Valves. All safety valves shall be kept clean and in working order.

C-19. The capacity of safety valves shall be calculated, as provided for in Pars. 269–290 (inclusive) of the Rules for the Construction of Power Boilers, under the following conditions and if necessary a larger safety valve installed; when the allowable working pressure of a boiler has been reduced, when a boiler is equipped with increased stoker capacity or when a change in fuel permits increased combustion.

C-20. Whenever the stipulated blowing pressure of a safety valve is 10 per cent higher or lower than the pressure for which the spring of the valve is designed, the safety valve shall be equipped with a new spring complying with the requirements given in Pars. 269–290 (inclusive) of the Rules for the Construction of Power Boilers.

C-21. When a safety valve spring has weakened and has been further compressed to secure the stipulated blowing pressure, an examination of the spring shall be made in order to insure its compliance with the rules given in Pars. 281, 282 and 284 of the Rules for the Construction of Power Boilers.

C-22. Where boilers are set in battery and operating under the same working pressure and some of the boilers have allowable working pressures greater than others, all safety valves shall be set to blow off at a pressure not in excess of that allowed on the weakest boiler.

C-23. Safety valves shall be tested at least once a day by gently raising the valve off the seat by hand and, when practicable, shall be tested daily by raising the steam pressure to the blowing pressure of the safety valve. Small chains or wires attached to the levers of pop safety valves and extended over pulleys to other parts of the boiler room may be used.

C-24. When a safety valve sticks or fails to operate at the stipulated blowing pressure, no attempt shall be made to free it by striking the body or other parts of the valve but the boiler shall be taken out of service and the safety valve examined.

C-25. The safety valve, when blowing, shall be checked against the boiler gage and when the pressure noted on the boiler gage varies more than 5 lb. from the stipulated blowing pressure, the boiler gage shall be tested and if found correct, the safety valve shall be corrected.

C-26. The setting and adjusting of safety valves shall be done by a competent person. When safety valves are set or adjusted, the level of the water in the boiler shall not be above the highest gage cock.

C-27. In order to insure that the freedom of the spring is in compliance with the Rules given in Pars. 282 and 284 of the Rules for the Construction of Power Boilers, it shall be tested whenever the valve spring is adjusted.

C-28. After a hydrostatic test has been made, special care shall be taken to see that the safety valve is immediately restored to its proper operating condition.

C-29. Leaking safety valves shall be repaired or replaced as soon as discovered.

C-30. Care shall be exercised to prevent the accumulation of dirt, scale or other foreign matter between the coils of the spring.

C-31. The discharge from the open end of escape pipes shall be unobstructed and, if practicable, inside of the boiler house within hearing of the operator.

C-32. All supports and anchors that are attached to the escape pipe, shall be tested every six months and the proper tension maintained.

C-33. Escape pipe drains shall be examined monthly and the escape pipes shall be disconnected once a year in order that the drain may be kept free and clear at all times.

C-34. Intercommunicating Valves Between Systems of Different Pressure. Where intercommunicating systems of different steam pressures are installed with boilers on each system, the boilers on the low-pressure systems shall be equipped with non-return check valves. All low-pressure headers and their outlets shall be protected by a relief valve or valves whose combined capacity shall be equivalent to the total amount of steam that can pass from the higher-pressure system into the lower pressure system. Where a reducing valve is used, a hand valve shall be installed. Also a steam gage shall be installed at a convenient point for the guidance of a person when operating the hand valve in lieu of the reducing valve.

C-35. Whenever the total amount of steam that can pass from a higher-pressure system into a lower-pressure system has been increased, the relief-valve capacity shall be increased an equivalent amount in accordance with Par. C-34.

Feedwater Control

C-36. Pump Regulators. Feed-pump pressure regulators shall

be maintained in good condition and shall be frequently tested under closed discharge. When duplicate pump is not installed the pressure regulator shall be by-passed.

C-37. When feedwater pressure increases above normal, the feed lines shall be examined for possible choking due to scale or other causes.

C-38. Feedwater Regulators. Where feedwater regulators are used they shall be by-passed and shall be kept in good working condition, but shall not be depended upon to maintain a proper level of water in the boiler.

Excessive Combustion

C-39. Damper. Damper regulators and draft-control devices shall be kept in good working condition and shall be so installed that any failure of or accident to the mechanism of the damper will cause the damper to open and not to close.

C-40. Fuel Supply. Fuel-supply regulators shall be kept in good working condition and shall be so installed that any failure of or accident to the mechanism of the regulator will shut off the supply of fuel to the boiler and, once having shut off the supply of fuel, will not automatically resume the supply of fuel.

Operation

C-41. Manipulation of Valves. When cutting in a boiler, the stop valve shall be opened slowly to avoid water hammer and, where non-return check valve or stop and check valve is not installed, it shall be opened only when the pressure in the boiler is exactly the same as the pressure in the main boiler header. Where a non-return check valve or stop and check valve, as the case may be, is installed, it shall always be used automatically for cutting in and cutting out of the boilers; the main stop valve, in cutting in a boiler, shall be opened when the pressure on the boiler is still 10 or 15 lb. less than that on the main and, in cutting out the boiler, the main stop valve shall not be closed until after the non-return check valve has closed. Care shall be taken to drain the piping between the main stop and non-return check valves before cutting in the boiler.

WEAKENING OF STRUCTURE

Overheating

C-42. Lack of Water Supply. Special and constant care shall be exercised to maintain a proper and uniform water level in the water gage glass and to provide a continuous rather than intermittent supply of water to the boiler.

C-43. The water tender or any operator responsible for maintaining water in the boiler shall not permit any inattention, other duties or reliance upon automatic devices to interfere with the performance of his duty in preventing low water level in the boiler.

C-44. Where practicable, a duplicate source of supply of feedwater, pump or injector and piping systems to the boilers shall be installed. Where two systems of piping to the boilers are used, it is recommended that the two systems enter the boiler at different points. Feed pumps and injectors shall be maintained in good condition.

C-45. Leaks in the feed discharge line or elsewhere shall be stopped as soon as possible.

C-46. Sufficient water shall be maintained in feedwater tanks to prevent loss of suction in the feed pumps and, where hot water is fed to or allowed to splash in feedwater tanks, sufficient water shall be maintained in the tank to prevent entrainment of vapors.

C-47. Feed lines shall be free from objectionable vibration due to feed pump.

C-48. Where electrically driven feed pumps are used, there shall be maintained, ready for service, steam-driven feed pumps of sufficient capacity to safeguard the boilers in case of failure of electric power.

C-49. Restricted areas in feed lines, such as meter tubes, orifice plates, etc., shall have a by-pass equivalent in size to the pipe line.

C-50. Where economizers are installed in the feed line, they shall have a by-pass equivalent in size to pipe lines.

C-51. All feedwater tanks shall be cleaned out frequently to prevent the accumulation of objectionable sediment.

C-52. When feedwater tanks are installed, and the water level cannot be observed easily by the water tender, suitable water-glass or water-level indicators shall be installed.

C-53. Frequent inspections shall be made to detect scale and defective check valves in the feed line.

C-54. Feedwater regulators or other automatic devices shall be maintained in good working order.

C-55. If difficulty is experienced in maintaining the proper water level, the combustion shall be checked and the draft dampers and ashpit doors closed until the cause is discovered and corrected.

C-56. If the level of the water is not visible in the water glass, the gage cocks shall be tested to ascertain whether the level of the water is above or below the water glass. If the level is below the water glass, the supply of fuel and air shall be stopped and the dampers and ashpit doors closed. The feedwater valve shall be closed and under no circumstances shall any attempt be made to admit water to the boiler. The fire shall be hauled or in case of stokers or chain grates, the grates shall be kept in motion and the fire doors shall be left open. Water from fire or other hose shall not be thrown upon the fire. The safety valve shall not be opened, steam outlet valves shall not be changed nor shall any change be made that will cause a sudden change in the stresses acting upon the boiler. The blow-off valves shall be examined and, if found defective, repaired. The cause of the failure of water supply shall be determined and remedied.

C-57. Where both cock and valve are used in the blow-off line, the cock shall be placed between the valve and the boiler. All blow-off cocks and valves shall be kept free from leaks and in good working order.

C-58. Blow-off piping shall be extra heavy from boiler to valve or valves, and all fittings between the boiler and valves shall be of steel. Blow-off pipes shall be so located that all exposed portions within the building, and within any pipe tunnel, opening directly into the boiler room, can be inspected and such portions of the blow-off piping which occur within the boiler room, or within any pipe tunnel opening directly into the boiler room, shall be installed to withstand full working pressure of the boiler.

C-59. Blow-off valves shall be in such location that they are accessible, and if located in a trench or tunnel, an extension shall be applied to the valve stems so that they may be operated from the floor, or some convenient location.

C-60. In operating blow-off cocks and valves, they shall be opened and closed carefully and slowly; care shall be exercised to make sure that when the valves or cocks are closed, they are closed tight. Where both valve and cock are used in the same blow-off connection, the cock shall be opened before the valve and closed after the valve. In blowing off a boiler, the valve or cock shall be opened half way and remain so until one inch of water has been blown down and then the valve shall be fully opened and remain so until the blowing off is completed.

C-61. The amount of blowing off shall depend upon the amount of suspended matter in the feedwater, the number of hours per day that the boiler is in service and the rating at which the boiler is in operation; the minimum amount shall be one gage every twenty-four hours, except where the amount and frequency of blowing down is determined by chemical analysis. The blowing off shall be done when the boiler is operating at its lowest rating; a boiler shall be blown off as soon as it has been cut off the line and just before it is cut in.

C-62. When the operator is blowing down a boiler and cannot see the water glass, another operator shall be placed to watch the water glass and signal the operator blowing down the boiler.

C-63. The pipe and fittings between the blow-off valve and the boiler and their insulation shall be occasionally inspected in order to maintain them in good condition.

C-64. When practicable, the end of the blow-off line shall be visible in order to detect leakage.

C-65. Fouled Heating Surface. Boilers shall be kept free from scale, mud and sediment as far as possible at all times, particular care and attention being given to the heating surfaces, tubes and fire sheets.

C-66. Waters containing salt, magnesium chloride or nitrates should not be used in the boiler without outside treatment as they will cause pitting and foaming in the boiler.

C-67. Feedwaters should be made slightly alkaline with con-

mercial sodas or lime where free organic or mineral acids are present.

C-68. Feedwaters should be treated with commercial sodas where the impurities in 10,000 gallons of water are precipitated by one pound or more of carbonate of soda.

C-69. Where feedwaters contain 3 grains per gallon or more of carbonate of soda, or its equivalents in other sodas, the soda concentration within a boiler should not exceed 100 grains per gallon.

C-70. All feedwater should be passed through a heater before it is introduced into the boiler in order that any temporary hardness will be eliminated as far as possible and precipitated in the heater from which it can be removed easily.

C-71. Feedwater which is treated should be raised in temperature to a minimum of 180 deg. fahr., and the treatment should take place in an external vessel or heater separate from the boiler, which is suitable for receiving the precipitate formed by the elimination of the temporary hardness and the reaction of the chemicals thus obviating use of the boiler as a sludge tank as far as possible.

C-72. Commercial boiler compounds should not be used without intelligent supervision or without an exact understanding of their chemical composition, the exact nature of the scale-forming material in the water and the reaction which will be brought about by their combination.

C-73. Where water-softening apparatus is found necessary, operator should check by analysis, with frequency, the quantity of chemicals or other substances used in the softener against the scale-forming matter in the water.

C-74. Proper technical supervision should control the operation of any water softener.

C-75. Recommended procedure for treatment of boiler feedwater to obtain the best results and greatest assurance of safe operation is the daily sampling and analysis of feed and blow-down water, regulation of the blow down and prescription of feedwater treatment by some qualified chemical engineer at frequent intervals.

C-76. Where carbonate of soda or soda ash is used in the treatment of feedwater, it must be kept at a point below $\frac{1}{2}$ of 1 per cent normal alkaline strength or concentration to avoid pitting; that is about 15 grains per gallon, normal solution of sodium carbonate being 5.3 grams to 100 cc.

C-77. Graphite should be used with caution as a boiler-water treatment. It tends to choke up connections to draft regulators, steam gages, etc.

C-78. Kerosene should be used with caution in boiler as a scale remover. It is liable to leave behind inflammable gases, which have caused dangerous explosions in the past on the introduction of lights into the boilers, and it may distil into elements which will attack gaskets and joints of piping and fittings.

C-79. When soda ash is used to remove scale from boilers, it must be done under proper supervision, and when conditions are bad it is recommended that daily record be made of alkalinity and chloride content of the water in each boiler.

C-80. Where priming is experienced, a sample of trap discharge from steam main near boilers shall be tested for chloride and alkalinity frequently and the result recorded.

C-81. When scale is being removed from boilers by the treatment of feedwater, care must be used not to bring it down too fast as it may accumulate in piles and patches on the sheets over the fire causing bagging or blistering of the plates.

C-82. A piece of zinc should be hung in the interior of boilers which are subject to electrolytic action and a tendency to pitting. There should be a good electrical contact of low resistance between the boiler structure and the zinc, which must be fitted in a basket designed to prevent the danger of the disintegrated zinc from fall in a pile on the shell of the boiler or plugging tubes in the vicinity. Zinc should not be used where boiler compounds are being employed for treating feedwater.

C-83. Care shall be used to prevent the entrance of oil into a boiler, as it will collect in clots on the heating surfaces, causing bagging or rupture.

C-84. Where there is a possibility of oil in returns, feedwater heaters should be provided with oil filters. Entrainment return lines should be passed through some suitable filter bed such as excelsior, exhaust mains should be dripped and the oil separated out.

C-85. Discharge from heaters or heater coils for fuel-oil installations shall be wasted or diverted to other uses to prevent any oil reaching the boilers.

C-86. When boilers are taken off the line for cleaning and washing, they should not be blown down and opened before the brickwork of the setting has cooled, otherwise the scale will be baked hard on the metal surfaces making its removal difficult.

C-87. Boilers should be blown down at regular intervals under the supervision of some competent person for the removal of mud which has precipitated because of the elimination of temporary hardness in the water by heat, removal of scale-forming elements by treatment, and the ordinary settling down of impurities in general.

C-88. It is recommended that a feed trough be used with water-tube boilers which have longitudinal upper drums into which the feed line is connected, for the purpose of catching and facilitating removal of mud deposited from the temporary hardness in the water.

C-89. Boilers should be taken off the line at such regular intervals, especially where the water is being treated, blown down, opened and given a thorough washing, as to clear all tubes and heating surfaces of mud, slime and loose deposits.

C-90. Boiler tubes should be turbined as required, to free tubes from scale but with proper feed treatment and control very little turbining should be necessary. Removal of scale from the exterior of fire tubes by vibrating them with internal cleaner or hammer must be practiced with caution as it is a serious strain on thin tubes.

C-91. Boilers shall be provided with the necessary manholes and handholes so that all areas can be reached, lighted, inspected and washed with facility.

C-92. Soot should be removed from heating surfaces frequently. In addition to the use of mechanical soot blowers, the front tubes of many water-tube boilers should be blown and cleaned over the fire with a hand-operated steam or air lance.

C-93. The engineer in charge should make inspections of the internal and external surfaces of the boiler at frequent intervals, logging the result of such inspections in detail to form a basis of comparison from time to time.

C-94. Excessive Combustion. Care shall be used that there is no weakening of the boiler structure due to fire cracks, crystallization of parts, etc., because of an increase in the rate of operation, where stokers are substituted for hand firing, or there has been a change from low- to high-grade fuel, etc.

C-95. Furnaces shall be guarded against leakage of cold air which striking against hot surfaces of the boiler cause dangerous stresses.

C-96. In case of stokers and oil fires care shall be used to keep furnace temperatures down to safe limits and to see that only the best available refractories are used.

C-97. Oil flames shall not be allowed to impinge on side walls or arches as they will cause excessive spalling and endanger safety of the structure. Air pressure in the furnace shall not be allowed as it will force hot gases out through any crevices in the setting and tend to destroy it.

C-98. Secondary Combustion and Flaming Through. Where possible, the combustion chamber and the gas passages with their connections shall be constructed without blind pockets or spaces where unburned gas can accumulate; where such pockets or spaces are unavoidable, they shall be properly ventilated.

C-99. Where waste gases are used as fuel, they shall be bypassed to the chimney.

C-100. Before lighting a fire, the combustion chamber and gas passages shall be thoroughly ventilated. After the ventilation (in a gas-, oil- or pulverized-fuel-fired boiler) a torch or other flame shall be placed in the combustion chamber before the supply of fuel is admitted. If a torch is used the operator shall stand clear of the opening. In oil-, gas- or pulverized-fuel-fired boilers, a torch shall be used to light all burners until the brickwork becomes intensely hot and even then when all burners are out.

C-101. In the event of flare back or the snapping out of burners, the fuel supply shall be shut off and the boiler thoroughly ventilated before the fire is again lighted.

C-102. Secondary combustion shall be prevented by admitting sufficient air at all times to guarantee the complete combustion of the fuel before the gas has traveled one-half of the distance from

the fire bed or burners to the exit of the setting. Care shall be exercised to prevent the leakage of air into the latter passes and thus burning the gases in the latter passes.

C-103. When a fire is banked, the admission of air below the fire shall be checked and only sufficient air admitted to the combustion chamber above the level of the fire bed to prevent the accumulation of gases of imperfect combustion. The damper in the uptake shall be left slightly open or perforated to insure a slight draft.

C-104. In shutting down a boiler, the air supply shall be maintained until after the fuel supply is discontinued and in the case of oil-fired boilers until any oil on the floor of the combustion chamber is consumed. After all combustion has ceased, the air supply shall be continued only until the combustion chamber and gas passes are thoroughly ventilated.

C-105. Localized and Uneven Heating. Ample time shall be allowed for raising steam pressure to prevent uneven heating of the boiler and setting, especially where circulation of water may be sluggish, as in internally fired types; also on new installations where uneven expansion might effect the brickwork.

C-106. The surfaces in the steam space of drums shall not be exposed to the direct heat of the combustion chamber, or to the direct products of combustion. Baffles and brickwork shall be kept in repair at all times to prevent surfaces in the steam space of drums from becoming exposed to the direct heat of the combustion chamber.

C-107. When superheaters are a part of the boiler, some means shall be taken, when firing up, to blank off the direct affect of the hot gases by a damper, unless superheater is flooded or unless they are of a type protected to withstand the heat.

C-108. Cast-iron or wrought-iron sleeves of ample size shall be provided wherever pipes pass through the brickwork, to provide for expansion and contraction.

C-109. Rivet heads shall not be exposed directly to the heat of the combustion chamber, except where they are within the water space.

C-110. Boilers shall not be emptied until brickwork cools, as uneven expansion may take place.

C-111. Damper Regulation. Each boiler shall be provided with a draft gage and a recording temperature device in the stack used in connection with each battery. Every boiler shall be provided with a back damper which can be operated and adjusted conveniently from the firing floor by the fireman on watch.

C-112. Smoke flues from batteries of boilers shall be baffled in such a way as to equalize the draft between the boilers.

C-113. Where draft-control systems are used they shall not be considered as relieving the fireman of responsibility. He shall be alert at all times to detect unusual conditions which may cause excessive combustion and affect the safety of the structure.

C-114. Where electric devices are used to actuate draft-control apparatus, the operator shall use care to see that the current does not fail and to handle the situation promptly in case of failure of the electrical supply.

C-115. Should the damper connection break, the mechanism shall be arranged so that the damper will open automatically and the fuel supply shut off automatically.

C-116. Damper regulators, where used, shall be preferably of the so-called "dead beat" type with valve lever so arranged that after pilot valve has been opened by a slight shifting of the pressure-actuated lever, it will be returned to closed position by the movement of the piston rod which handles the damper, thus causing gradual changes in the draft condition.

C-117. Damper regulators and draft-control apparatus shall maintain the steam pressure within a total range of not more than 5 lb. for boilers carrying under 150 lb. gage pressure, and within 10 lb. for boilers carrying higher pressure.

C-118. In the case of oil-burning or powdered-coal furnaces, the back damper shall be opened wide when the fire is to be lighted.

C-119. Insulation. Blow-off pipes shall be protected from the products of combustion by firebrick or other heat-resisting material so arranged that the pipe may be inspected.

C-120. Structures supporting the boiler, or structures which are a part of the building, shall be protected from the heat of the combustion space by insulating material, or air space, and shall not be subjected to temperatures above 600 deg. fahr., which might affect the strength of the material, and cause strains to occur due to expansion. This applies particularly to structures located between the settings of boilers in a battery.

C-121. With the suspended settings the steel work shall be so designed and be of sufficient strength and rigidity to eliminate any strain on the brickwork, under conditions of temperature which might cause the steel to expand or contract.

C-122. Firebrick linings shall be set in such a manner that when heated the expansion will not affect the outside walls.

Internal Corrosion

C-123. General. The interior of all parts of boilers shall be examined frequently and watched continually for evidences of corrosion in the shape of grooving, pitting, wasting away or thinning of metal.

C-124. Upon the observation of any indications of corrosion, steps shall be taken promptly to counteract the condition. In case of steaming boilers, clear water or grayish color in the gage glass may be an indicator of safe water, while reddish or blackish colored water may be an indicator of corrosion in the boiler or its connections.

C-125. Boiler operators shall watch their raw-feed supply to guard against the possibility of corrosive elements becoming mixed with the water.

C-126. The presence of air and oxygen may be detected by warming a sample of boiler feedwater in a glass flask and noting the bubbles which collect.

C-127. Feedwater shall be examined from time to time for organic matter both by filtering and by testing with pure sulphuric acid which, when added to a sample of the water in test tube, will turn it brown should organic material be present.

C-128. Chlorides which are particularly active agents of corrosion shall be tested for by the addition of silver nitrate to a sample of water which contains a little potassium chromate indicator which gives a brownish red color in presence of chlorides.

C-129. A test for acidity shall be made often, particularly if the source of supply of feedwater is a river or pond in a manufacturing district. This test can be made by taking a sample of raw water, adding a drop of methyl orange which will turn the sample yellow if it is alkaline and pink if acid and corrosive.

C-130. Where complete water analyses are available, it is recommended that they be checked by Stabler's corrosion formula which classifies them in accordance with their acid-forming tendencies. Stabler's coefficient of corrosion is

$$C = H + 0.116\,Al + 0.0361\,Fe + 0.0828\,Mg + 0.0336\,CO_3 + 0.0165\,HCO_3$$

where the CO_3 term represents the carbonates, the HCO_3 the bicarbonates, and all the terms are expressed in parts per million. Where C + 0.0503 (calcium ion) = negative quantity, there will be no corrosion due to acidity. Where C is negative but C + 0.0503 Ca is positive, corrosion may or may not occur, the probability varying directly with the value of expression C + 0.0503 Ca.

C-131. Water shall be kept slightly alkaline when there is reason to expect acidity, and possible corrosion. This maximum alkaline strength should not exceed one-half of one per cent normal (about 15 grains per U.S. gallon) unless under the direction of an expert feedwater chemist or engineer. Normal alkaline strength is 5.3 grams of soda ash or sodium carbonate to 100 cc. of distilled water.

C-132. The percentage of normal-strength alkalinity shall be ascertained with frequency and checked by the formula:

$$P = \frac{Qn}{S}$$

where

P = per cent normal strength
Q = number cc. from testing burette
n = percentage of normal strength of acid used in testing burette
S = number cc. in sample of water being tested.

C-133. This test for alkalinity shall be made by titration using

$\frac{N}{5}$ H_2SO_4 (i.e., one-fifth normal sulphuric acid) in burette and phenol-pthalein indicator which changes from pink to clear water at the end point. Tests made for the detection of possible tendencies to corrosion must be made not only on the raw water but especially on the blow down water of the boiler.

C-134. Feedwater. Air and gases like oxygen, carbon dioxide and sulphur dioxide either in solution or mechanically mixed with feedwater are corrosive agents. Such feedwater should be passed through an open heater which has a top breather pipe to the air through which the gas may escape.

C-135. Where considerable trouble is experienced from air, oxygen and carbon dioxide in feedwater, some form of deactivator should be used. Closed heaters should not be used where air and gas is encountered in feedwaters as they tend to collect the gas, are corroded rapidly, and are dangerous for that reason.

C-136. Where air and gas are carried into the boiler they tend to lodge below the water line in the form of bubbles which make pits in the metal. In such cases the feed shall be treated with lime or caustic soda to make the water slightly alkaline (see preceding paragraph on safe limit), the water should be fed above the water line in the form of a spray and in extreme cases a vacuum pump attached to the open heater to clear it of air and gas.

C-137. All feedwaters which have magnesium compounds in them must be regarded with suspicion. Magnesium chloride under the action of heat decomposes and gives off hydrochloric acid. Magnesium sulphate, if salt is present, will produce hydrochloric acid under the action of heat. Such waters should be treated with carbonate of soda.

C-138. Feedwaters which contain sea water will cause corrosion and should be treated with sodium carbonate.

C-139. Boiler waters which contain calcium sulphate and organic matter shall be taken care of as they will produce sulphuric acid, a dangerous corrosive agent.

C-140. Calcium sulphate scale shall be removed from boilers promptly as it will decompose into sulphur dioxide and oxygen under the action of heat. This free oxygen attacks the metal of the boiler corroding it rapidly.

C-141. All nitrates are corrosive agents, and where they occur shall be neutralized by treating the feedwater.

C-142. Ammonium carbonates which come from barn and outhouse drainage are a source of danger which must be guarded against as they are very corrosive.

C-143. Acids in general must not be allowed to get into feedwater supply. Rivers which flow past manufacturing towns frequently pick them up; they may come from the decomposition of fats, vegetable oils and greases which were compounded into lubricating oils used in the plant; water from swamps and bogs may contain humic acid, tannic acid and carbonic acid; some patented boiler compounds contain free acids like tannic acid; coal-region water contains sulphurous acid, etc.—all are corrosive and their possible presence should be checked regularly by means of the acid test described in the preceding paragraph.

C-144. Pure water and distilled water shall be used with caution as boiler feed. The pure water has a marked capacity for dissolving iron. Distilled water always has an equal volume of CO_2 in it. Both are corrosive and should be made alkaline with lime or soda.

C-145. Rain water, especially where it comes from roofs of buildings near manufacturing centers, will contain more or less soot, salt and sulphur dioxide, all of which are corrosive agents which shall be guarded against.

C-146. Where coagulants are used, especially alum (sulphate of aluminum) decomposition may take place from the heat of the boiler, which sets free sulphuric acid, a dangerous corrosive agent.

C-147. Stray electric currents are possible in power houses, giving rise to obscure electrolytic reactions in the boilers which will cause pitting of boiler metal. For this reason boilers shall be grounded thoroughly.

C-148. Electrolytic action should be avoided as far as possible by the insulation of copper and brass pipes from the boiler structure, by the use of iron rather than brass or copper ferrules at tube ends when needed, by avoiding contact of dissimilar metals in the boiler structure, and by using care in keeping coal, cinder, scale, chips of copper, brass and lead out of the boiler.

C-149. Mill scale from tubes and shell plates shall be removed from boilers as it tends to promote electrolytic action and corrosion, especially where salt is present.

C-150. Defective circulation and unequal strains on members of the boiler structure tend to promote corrosion and must be checked where trouble is experienced.

C-151. Where pitting is experienced, the surface of the metal shall be cleaned carefully, the pits filled with zinc oxide paste to decrease the possibility of gas lodging in their cavities and to check the corrosive action. Where slight grooving and thinning have occurred the boiler drum shall be given an inside coat of portland cement or zinc paint.

C-152. Boiler Out of Service. When boilers are taken out of service for any length of time care shall be used to prevent corrosion. If they are to be left empty, they shall be oiled down as they are emptied, dried out with the help of a hot-air stove, have suitable amount of quicklime placed on boards in the interior and finally be closed tightly.

C-153. Boilers shall, if idle for considerable periods, be opened up each three months for examination and the renewal of the quicklime.

C-154. If idle boilers are to be left with water in them, this water shall be made slightly alkaline and the boiler pumped full of water. This water shall be heated to a moderate temperature for a short time to eliminate all the air possible. The boiler shall then be closed tightly, allowed to cool and shall be kept cold. In such cases a piece of bright, clean iron shall be hung in the closed boiler in such a way that it can be removed and inspected for rust and corrosion at regular intervals.

C-155. Where boilers are idle long periods filled with water, great care shall be used to keep this water cold as the maximum amount of corrosion is promoted by lukewarm water. For this reason feed valves and all steam connections shall be tight at all times.

External Corrosion

C-156. Leaks, etc. Boilers in service are always exposed to external leaks of different kinds which tend to corrode the shell. The operator shall guard against leaky safety valves and steam mains which drip on the boiler and cause external corrosion, especially where the water runs under protective coverings.

C-157. Leaky manholes and handholes particularly where ash and soot can collect are especially dangerous as they corrode the shell rapidly. Such places shall be kept clean and tight.

C-158. Boiler operators shall keep under observation at all times the blow-off pipe nipple that screws into the mud drum. Corrosion is especially liable to weaken the pipe at this point causing possibility of serious accident.

C-159. The roof over boilers shall be maintained in good condition as roof water leaking down on settings tends to destroy them as well as to corrode the boiler itself.

C-160. Quenching water shall not be played on hot ash and cinder in boiler pits as there is danger of wet ash being carried up on to the shell and tubes of the boiler causing corrosion.

C-161. Care shall be taken to see that ashes do not come in contact with the boiler at any point.

C-162. Leaky tubes shall be rolled or replaced promptly to avoid possible corrosion of the tube sheet.

C-163. Boiler out of Service. When the boiler is taken out of service it shall be cleaned externally and inspected for wet ash and soot.

C-164. When boiler is to be out of service for a long period it shall be given a coat of red lead, black japan, or tar paint to prevent external corrosion. The damper shall be closed and lime placed on several points in the setting to dry the air as much as possible. All openings into the setting shall be closed.

C-165. Where boiler has been taken off the line for an idle period, it shall be made certain that all feed and steam valves are shut and do not leak.

Erosion

C-166. Soot blowers shall be supplied with practically dry

steam; they shall be well drained before using. Care shall be taken to prevent too direct an impingement with a steam jet upon the tubes and tube sheets.

C-167. In using a steam lance, care shall be taken not to blow with too much force or for too long a period upon any one point, particularly about the lower end of vertical water tubes.

STRESSES OTHER THAN INTERNAL PRESSURE

C-168. Boiler Supports. Foundations for steam boilers must be of ample size to carry the load, and where large concentrated loads fall within a small area of the foundation, as in the vertical types of boilers, the foundations should be reinforced and spread to prevent any settling which might throw the boiler out of line. When the boilers are set in a battery, and when the foundations are not tied together by reinforcement, the joints in connecting pipes shall be broken open occasionally to see that no strains have been placed upon the piping on account of settling of any of the boiler foundations.

C-169. Foundations and structures supporting a steam boiler shall be built to withstand any strain which may be transmitted to them by expansion or contraction of boiler or supports, and shall be tied together in such a manner as to maintain their proper relation.

C-170. Vertical fire-tube or water-tube boilers whose bases cover a small area shall be carefully shimmed to distribute the load equally at all points. All shims shall be of steel or iron and properly secured or grouted.

C-171. Steel structures supporting boilers shall be carefully protected from water from roofs or steam leaks, and wood or inflammable material shall never be stored close to supporting structures.

C-172. Supports for water-tube boilers shall be so designed that unequal strain shall not be brought upon the tubes by expansion or contraction. Structures surrounding the boiler shall provide for any expansion which may take place and eliminate any possibility of straining the tubes or injuring the boiler setting.

C-173. On suspended type of settings care shall be taken at all times to see that the load is properly distributed over all points of suspension.

C-174. Pipe-Line Supports. Pipe lines connected to boiler shall be installed with provision for expansion and contraction, and expansion bends shall be used where possible. Pipe lines shall be braced to prevent strains on boiler or connecting pipe lines, and supports shall be of sufficient strength and designed to withstand strains set up by possible water hammer or vibration.

C-175. Pipe-line supports shall not be attached to temporary structures which might be removed, or to wooden structures which might be injured by fire. Supports for piping shall not be attached to wooden or steel structures such as floor or roof beams, which might be deflected by changes in load.

C-176. Supports of Equipment or Other Structures. When stacks are supported from structures directly above the boilers, or from the boilers themselves, care shall be taken to protect all steel work from corrosion caused by water at this location running down on the stack, or from the roof.

C-177. Shafting and belting shall not be located over the boiler in such a position as to cause injury to the pipe lines, or cause strains on the boiler if an accident should occur to the belt, or the line of shafting. Supports for shafting shall be of sufficient rigidity, or, if necessary, separate structures should be provided the shafting to prevent vibration being carried to pipe lines, or to the boiler.

C-178. Safety-Valve Escape-Pipe Supports. To prevent injury to the boiler and setting, if necessary a safety-valve escape pipe shall be installed to carry the discharge or any condensation away. Escape pipes should be supported to prevent any strain upon the safety valve.

C-179. Supporting Columns Between Settings. Where supporting columns between settings, or near boilers, are exposed to corrosion, they shall be set on concrete piers at least one foot above the floor level, or shall be encased in concrete at least 2 in. thick, to a point above which corrosion will not occur. Supporting columns not protected by concrete against corrosion shall be exposed so that they can be thoroughly inspected, and shall be kept well painted.

C-180. All structures over boilers, whether they are part of the boiler installation or building structures, shall be inspected regularly to see that corrosion does not occur, and shall be kept well painted at all times.

C-181. Supports of Blow-off Lines. Blow-off pipes shall be supported and anchored to prevent strain being put on the boiler structure on account of expansion or contraction.

MOLECULAR CHANGES

C-182. Crystallization is caused by alternate heating and cooling of the boiler metal and can be minimized by avoiding frequent and sudden changes of temperature.

C-183. Embrittlement may be caused by too high concentration of soda in the boiler water and can be avoided by maintaining a concentration of less than one-half of one per cent normal alkalinity.

MECHANICAL INJURIES

C-184. All boilers, with their auxiliaries and appurtenances shall be located, as far as practical, where they will be least liable to damage from external forces such as building failures, flywheel explosions, flood, fire or explosions from the storage of inflammable material, belt transmission failures, etc.

C-185. Tube Cleaning or Scaling. Power, for operating mechanical hammers and cleaners used in removing scale or slag, shall be generated outside of the boilers being cleaned. When such tools are actuated by air, steam or water, they shall be operated at the lowest pressure sufficient to accomplish the work when the motion of these tools, actuated by hot water or steam, is generated within the tube, care shall be taken not to heat the tube to the extent of causing undue strains by expansion. Mechanical hammers and cleaners shall not be operated for more than a few seconds at a time at any one spot.

C-186. Loose Connections. The fastenings of all interior fittings such as braces, baffles, feed troughs, gratings, zinc baskets, dry pipes, etc., shall be maintained secure and free from lost motion.

C-187. Repairs. All repairs and replacements shall be subject to the rules for similar material and workmanship as given in the Rules for the Construction of Power Boilers.

C-188. No repairs, other than those of a routine character, shall be made upon a boiler except upon and in accordance with the advice of authorized boiler inspectors as required in Par. 409 of the Rules for the Construction of Power Boilers.

C-189. All repairs shall be made as soon as possible and a record of all repairs upon boilers and upon any equipment or auxiliaries affecting the safety of the boiler shall be kept. A record of all repairs deferred shall be kept with the reasons for their delay.

C-190. All leaks, however small, shall be traced to their source and the proper remedy, not only to stop the leak but to prevent its recurrence, shall be applied at once.

C-191. No repairs shall be made upon a boiler or upon any of its equipment while it is under pressure.

C-192. The shell or drum of a boiler in which a typical "lap-seam crack" is discovered along a longitudinal riveted joint for either butt-seam or lap joints shall be permanently discontinued for use under steam pressure. By "lap-seam crack" is meant the typical crack frequently found in lap seams extending parallel to the longitudinal joint and located either between or adjacent to rivet holes.

C-193. Cracks caused by flexure of the metal shall be repaired by removing the part affected and replacing it with a new part. The new part shall be of greater strength than the defective part or other means shall be employed to prevent a recurrence of the trouble.

C-194. Where corrosion becomes dangerous or when cracks appear, the boiler shall be kept out of service until the affected parts have been repaired or replaced. No welding or patching shall be done except upon and in accordance with the advice of authorized boiler inspectors.

C-195. Where pits occur closely grouped or aligned and are deep enough to affect the strength of the material, the affected area shall be removed and replaced by a hard patch. Isolated pits, not affecting the strength of material, shall be prevented from becoming serious by cleaning the pit to bare metal, washing with strong alkaline solution and filling with zinc oxide.

C-196. Leaking rivets shall be calked about the edge of the head and, if the leak continues, the rivet shall be removed and a new rivet put in. In removing the rivet, the center of the head shall be removed with a cape chisel, the remaining portions of the head driven inward and the rivet driven out by punch and hammer. If the rivet cannot be removed except by heavy hammering, the rivet shall be drilled two-thirds of the way through its body with a drill 1/8 in. smaller in diameter than the rivet and the remainder of the rivet backed out. Before driving a new rivet, the rivet hole shall be made clean and free from burrs and sharp edges.

C-197. No attempts shall be made to make a joint tight by putting undue stress on the bolts. If a joint cannot be made tight without stretching the bolts, the joint shall be opened and the cause of the poor joint determined and removed.

C-198. Increasing the leverage of a wrench by a piece of pipe or other means shall not be permitted as an average man with a

12 in. wrench will stretch a 5/8-in. bolt
18 in. wrench will stretch a 3/4-in. bolt
24 in. wrench will stretch a 7/8-in. bolt
30 in. wrench will stretch a 1 -in. bolt

This represents the limit which bolts should be expected to stand.

C-199. In cleaning gaskets from finished surfaces care shall be taken not to score or cut the surface.

C-200. When water tubes are sufficiently warped to prevent proper inspection for soundness and cleanliness, no attempt shall be made to straighten them in place; such tubes shall be renewed.

C-201. A water tube with a series of bags closely connected shall be replaced. Bags on water tubes shall not be set back. When the bag leaks or is abrupt with a tendency to pod or point to such an extent that there is an appreciable stretching of the metal or that there is a possibility of scale or deposit collecting in the bag, the tube shall be removed.

C-202. Tubes, which have been rolled until the thickness of the metal has been considerably reduced or until the life of the metal is probably destroyed, shall be renewed.

C-203. Tubes in fire-tube boilers, which have been rolled several times and still leak, may be improved temporarily by rolling and beading the tube and then inserting a tight-fitting ferrule of tube stock of a gage equivalent to that of the tube and of a length equal to three times the thickness of the tube sheet. The inner end of the ferrule shall be chamfered on the inner edge and the outer end shall be rolled and beaded after the ferrule is in place. When a ferrule is installed immediate steps shall be taken to replace the tube. There shall not be more than 10 per cent of the number of tubes in the boiler so equipped and not more than two adjacent tubes at any one time.

C-204. Tubes shall not be reended or pieced by autogenous welding.

C-205. In removing tubes exceptional care shall be taken not to injure the metal around the tube hole. A tube in being removed shall be cut with a flat chisel from the end to the header or drum at two places about 3/4 in. apart and the strip, between the cuts, raised from its seat and bent inward with a bar. The tube shall then be split through and beyond its seat with a tool as wide as the strip and ground to the curvature of the tube hole. A crumpling tool shall then be used to break in the end of the tube.

C-206. When a new tube is to be installed, the surfaces of the metal about the tube hole shall be made free from any projections due to mutilation and shall be thoroughly cleaned of scale or foreign matter. Any grooves, scorings or holes in these surfaces shall, if slight, be filled with iron cement or zinc oxide paste or, if of any magnitude, be built up by welding. The ends of the new tube, where they come in contact with the tube sheet or header, shall be made clean and smooth before the tube is put in place.

C-207. The expanding of the tubes shall be done by a competent person. Before expanding a tube, the expander shall be examined to see that it is equipped with the proper rollers, straight or tapered in the proper direction. Rolling shall be stopped when the rollers operate evenly all around the tube with sufficient pressure on the mandrel. The beading of a tube shall be done by rollers especially designed for the purpose or by a tapered mandrel driven into the end of the tube. The flaring, beading and welding of tubes and nipples and the amount of projection of the end of the tube beyond the tube sheet or header shall be in accordance with the rules given in Pars. 250, 251 and 252 of the Rules for the Construction of Power Boilers. The tube ends should be lightly rolled after beading.

C-208. The rules applying to the care of tubes and the surfaces about the tube holes are equally applicable to the care of the nipples and the surfaces about the nipple holes.

C-209. In removing slag from the exterior surfaces of a boiler or its tubes, care shall be exercised not to injure the metal.

RULES FOR INSPECTIONS

C-210. All power boilers shall be given one internal and two external inspections per year by the state or municipal inspectors having jurisdiction or by the inspectors of the insurance company carrying the risk. These inspectors are hereinafter termed authorized inspectors.

C-211. Similar inspections shall be made by the person responsible for the boiler plant as a whole who is hereinafter termed the plant inspector. Such inspections shall be supplementary to and in no wise considered as supplanting or superseding the inspections made by authorized inspectors. Such inspections shall be made in accordance with the following rules.

C-212. Between periodical inspections by authorized inspectors, the plant inspector shall closely observe the operation and condition of the boilers and shall report immediately to the proper authorities any serious defects, doubtful conditions or unusual occurrences.

C-213. An external inspection shall comprehend the superficial examination of the boiler, its appurtenances and connections and does not necessarily require that the boiler be off the line. It is a form of examination to check up care and management mainly.

C-214. The internal inspection of the boiler shall be a comprehensive and thorough examination in every detail, embracing particularly the determination of the suitability of the boiler for load and pressure carried, strength of its parts, possible deterioration in service, and advisability of its continuance under the pressure carried previously to inspection.

C-215. No particular preparations shall be necessary for an external inspection other than giving the plant inspector convenient access to the boiler and its connections.

C-216. The internal inspection shall call for somewhat extensive preparation, mainly the proper cooling and opening up the boiler together with a thorough cleaning of the boiler, including setting.

C-217. The cooling of boiler shall be done cautiously so as not to put undue stress on the heated surfaces and setting. The damper shall be opened wide and the ashpit doors opened allowing circulation of air in the usual way. The fire doors shall remain closed until boiler is cooled.

C-218. During the cooling process the large doors in the boiler front shall be kept closed in order to prevent rapid cooling of tube ends.

C-219. After the furnace and lining have become well cooled the fire doors may be opened as well as the clean-out door at the rear preparatory to sweeping out the accumulated ash and soot.

C-220. The walls, baffles, tubes and shell shall be thoroughly swept down and the ash and soot removed to give the plant inspector opportunity to examine the parts closely and to eliminate danger from hot contact.

C-221. The tubes shall be well dusted and cleaned with steam soot blowers before the cooling operation has commenced. Steam shall not be used to clean tubes of a cold boiler as the moisture cements the soot and ash into a hard mass difficult to remove.

C-222. When boiler and setting are thoroughly cooled the blow-off valve shall be opened and the water removed. Then the manhole and handhole covers shall be removed to allow circulation of air.

C-223. The inside of shell, drums and tubes shall then be washed down thoroughly to remove mud, loose scale, etc. The washing operation shall be conducted from above as far as possible to carry the material downward to blow-off or lower handholes.

C-224. Before the washing operation is commenced a wire-gauze screen of cylindrical form shall be inserted in each blow-off opening, projecting up into the boiler several inches, whose function

is to prevent loose pieces of scale from entering and clogging the blow-off pipe.

C-225. The plant inspector shall have available the data on the boiler, dimensions, age, particulars as to previous defects noted, if any, and shall proceed to check up the pressure carrying capacity of boiler subject to conditions found during complete inspection.

External Inspection

C-226. The plant inspector shall examine the boiler for level, noting whether or not there has been any tendency to settlement, especially the level of the top tubes in horizontal-return-tubular boilers. He shall see that proper provision is made for expansion toward the back of boiler.

C-227. Examination shall then be made of the feed connection to see that it is clear and in good working condition.

C-228. Examination shall be made for evidences of corrosion on exterior of shell from rain coming down stack and leaking roofs, valves and pipes.

C-229. Inspection shall be made to see if there is any leakage of flame on dry sheets, particularly at the back arch of return-tubular boilers, which should be entirely clear of rear tube sheet with sheet metal or asbestos rope covering gap. Tie rods and buck stays shall be examined for condition and possible shifting from place.

C-230. Where the boiler top is covered with brick or other material, it should be removed sufficiently to allow proper inspection of riveted joints.

C-231. The plant inspector should note proximity of overhead shafts or any machinery which might drop down on or strike boiler in case of accident.

C-232. The plant inspector should note the presence of lumber, or other material piled on boiler or setting for purposes of drying or storage and which may endanger the setting or the safety and accessibility of the apparatus.

C-233. A careful examination shall be made of the safety valve, its connection to the boiler, escape pipe, its drip, supports, etc. He shall also test the safety valve by hand.

C-234. The water glass, gage cocks, water column connections and blow-offs shall be tested to see if the connections are free. Boiler pressure gages and master gages shall be tested.

Furnace and Parts Exposed to Fire

C-235. The plant inspector shall go into the furnace for the examination of the exterior of the tubes, shell, brickwork, etc.

C-236. He shall examine carefully for bulges over the fire, leaky rivets, loose rivets, rivets out of alignment, corrosion, wasting away of plates, cracks, etc.

C-237. The plant inspector shall scrape the shell and tap it thoroughly with hammer to detect thin places. He shall check thickness of plates with steel-scale measurement. He shall examine joints and sheets over the fire particularly for possible fire cracks.

C-238. The plant inspector shall examine the setting for cracks, settlement and loose brick which may lean against the boiler. Where brickwork is used as insulation of steel supporting numbers it shall be examined to see that it is in good condition and that the air space, if any, is maintained. The furnace lining shall be examined for spalling, cracking and settlement. In vertical boilers, bridge walls shall be inspected to see that the mud drum is properly protected. The plant inspector shall examine baffle and check walls particularly for holes which may permit flaming through.

C-239. The blow-off connection should be examined carefully for corrosion and weakness where it screws into the boiler. The protecting cover of brick or tile should be intact and not interfere in any way with the expansion of the boiler or pipe.

C-240. Particular attention shall be given the tube ends and tube sheets in the case of horizontal-return-tubular boilers, the plant inspector noting any corrosion of the sheets, signs of leaking tubes, excessive thinning of the tubes from repeated rollings, and any cracks in the tube ends.

C-241. The plant inspector shall note any tendency to corrosion from leakage of manhole and handholes under tubes in tube sheets of return-tubular boilers.

Internal Inspection

C-242. The plant inspector shall enter the drums of the boiler to make personal examination of conditions, first making sure that they have been properly ventilated and that there is no inflammable gas present from oil used to coat the boiler as the water level is lowered.

C-243. Before entering the shell or drum the plant inspector shall see that the blow-off valve, the main steam valve and other valves are locked and the keys in his possession.

C-244. Careful examination of the interior of the boiler shall be made for pitting, corrosion, scale and thin places in shell. The upper half of drums in the steam space shall be examined particularly for signs of grease and oil.

C-245. The interior of the tubes should be examined for scale and deposits and the space between the tubes in case of return-tubular boiler made visible by lowering candle or small light between them for the purpose of making sure that there is no restriction of the circulation.

C-246. The location of the feed discharge and condition of the trough under it shall be noted. Dry pipes shall be examined to see that their openings and perforations are free from deposits. All interior fittings shall be examined for loose connections.

C-247. The interior face of the riveted joints shall be examined for condition of riveting, thinness of metal, corrosion, cracks, etc. The plant inspector shall note any wasting away and cracking of stays and braces. Particular note shall be made of any welded stays or braces.

C-248. The fusible plug, if used, shall be examined, the top scraped to expose the condition of the metal and the plug renewed in case it has seen a year of service. The surface of the boiler about the plug shall also be scraped.

Inspection of Appurtenances and Supports

C-249. An examination of the condition of the main header and its connections to boiler shall be made to ascertain that it is properly supported, that due allowance is made for expansion without throwing strains on the boiler, that the non-return stop-valves are in good working condition and so placed that there is no pocket in the connection to hold water.

C-250. The plant inspector shall note the position of the steam gage, gage cocks, ascertain that the pipes leading to the water column and water glass are level, and by leveling across the top row of tubes or from the position of the fusible plug check the position of the water glass.

C-251. Check pipe line and all exterior supports to see that the proper tension and alignment is maintained. Where boiler foundations are independent of building foundations, joints on the steam and feed connections shall be disconnected once a year to check possible settlements.

C-252. In addition to the above inspections, the plant inspector shall observe the condition of the interior of boiler at least once in every three months or at more frequent intervals if the boiler is opened for cleaning or repairs. Each time the boiler is removed from service, the plant inspector shall look for signs of defects where observations cannot be taken while the boiler is in operation.

C-253. A record of each inspection shall be kept in a uniform manner so that any change of condition can be definitely compared especially with reference to thickness of scale, corrosion, cracks, etc.

Care and Management

C-254. The plant inspector shall note particularly any evidences of carelessness in the care and management of the boiler and its appurtenances.

C-255. The plant inspector shall demand immediate remedy of any unsafe conditions or undesirable practices he may uncover and shall report fully on the results of his inspection to the owners of the boiler plant, promptly.

C-256. The plant inspector shall be furnished a copy of all reports of inspections made by authorized inspectors and shall see that all recommendations in such reports are promptly and carefully carried to completion.

RULES FOR ROUTINE OPERATION

PUTTING BOILERS IN SERVICE

C-257. Getting up Steam. In starting a new boiler or one that has been out of service for an extended period, see that the combustion chamber and gas passages are clean and in good repair. See that all clean-out doors are closed tight.

C-258. Operate and see that both inlet and outlet dampers are free and in good condition. Leave the back dampers open. Operate the stoker and draft fan to see that they are ready for service. Make sure that the grates are satisfactory and in place.

C-259. Examine the inside of the boiler and make sure that it is free from tools and foreign matter and that there is no one in the boiler; then close manhole openings.

C-260. See that blow-off valves, water column and water-glass drains, try cocks and feed valves are in good working condition and closed. Open vent valves.

C-261. By means of auxiliary feedwater connections, fill the the boiler with water to a level a little above the surface blow-off and, then close the auxiliary feed connections. Open and close try cocks and blow-down valves on water column and water glass in order to make sure that these connections are not stopped up.

C-262. Draw off water through surface and bottom blow-off valves until the level of the water in the boiler is at the bottom of the water glass and then raise the level of the water to a point about 1 in. below the normal water line by opening the stop valve in the main feed line.

C-263. Ease up on the stem of the main stop valve without lifting the valve off the seat in order to make sure that the valve is not stuck.

C-264. Open valves to steam pressure gage.

C-265. If coal is used as a fuel, cover the grate with a thin layer of coal and start a light fire. Where pulverized coal, gas or oil is used as a fuel, make sure that the back damper is wide open, create light draft, with fan if necessary, place torch or fire near burner to insure quick ignition and start light fire by admitting fuel slowly.

C-266. If the boilers use oil as a fuel and the system is new or has been out of service for a considerable period, first clean and examine the strainers and remove, clean and examine tips and burners. If compressed air is available, blow out the oil supply lines with air. Place and adjust burners and tips and work the air registers to see that they are in good working condition. Close individual burner throttle valves.

C-267. Remove any spilled oil about burners, fronts and floor and see that there is no oil on the floor of the combustion chamber. Ventilate the boiler by opening draft gates and dampers.

C-268. If no steam is available for oil pump and burners, raise steam in boiler by wood fire. Remove any excess accumulation of water in oil tank. Have oil pumps warmed up ready for use. Open suction-line valves and pump oil to burners. If oil lines are equipped with air chambers, charge them with compressed air. Examine oil lines and equipment for leaks.

C-269. Light the center burner by holding hand torch near and just under tip or burner standing well clear to avoid possible flare back. If torch is snuffed out before oil is lighted shut off the oil and relight the torch. Always use the torch for lighting burners until the brickwork is intensely hot and even then if all burners are out. Next light the adjacent burners but be sure that there is an excess of draft before lighting additional burners. Do not permit the oil to impinge on the brickwork or parts of the boiler.

C-270. Test the steam coils in the heater for oil.

C-271. After starting a light fire and if the entire setting is new, the fire should continue until the brickwork is dried out thoroughly which in the average case takes several days; if the combustion chamber only has been renewed keep the fire going about 48 hours. After the usual week-end shut down, a light fire should be carried for about one hour. Only in extreme emergency should steam be raised in less than a half hour. Do not permit the fire to generate a steam pressure until about thirty minutes before cutting the boiler into the line.

C-272. In case of a new setting, ease up on buck stays and tie rods to allow for possible expansion of the brickwork. After water becomes heated, check the level of the water in the glass with try cocks and examine blow-offs for leaks. After steam has escaped through the vent valves for a few minutes, close the valves.

C-273. After brickwork is dried out and the boiler heated, begin raising the steam pressure slowly, especially in internally fired boilers where the circulation is sluggish. Keep the water level constant. When the steam pressure approaches the working pressure, examine the boiler for leaks, blow out the pressure gage connections and test the safety valve by hand. Blow down boiler to remove sediment.

C-274. If the boiler is equipped with a superheater of the indirectly fired type not constructed to withstand the intense heat during the firing up period, see that it is protected before lighting the fire by flooding or by closing dampers installed for the purpose.

C-275. Cutting In. Drain very thoroughly the steam connections between the boiler and the header or steam main. Where a non-return check valve or stop and check valve is not installed, the stop valve shall be opened very slowly and only when the pressure in the boiler is exactly the same as the pressure in the header. If the main stop valve has a by-pass, the by-pass should be used until the pressures are equalized. In any case the stop valve shall be opened very slowly and the operator should stand by for a few minutes after the stop valve has been opened wide; if any disturbance or hammer occurs in the boiler or in the pipe line, close the stop valve at once. If a non-return check valve or stop and check valve, as the case may be, is installed, open the stop valve when the pressure in the boiler is 10 or 15 lb. less than the pressure in the header, and let the non-return check operate automatically.

FIRING BOILERS

C-276. Uniform Firing. Aside from the standpoint of economy, the fire should be maintained as uniformly as possible in order to avoid excess combustion, undesirable variations in temperature and possible gas explosions.

C-277. Cleaning Fire. Fires should be cleaned at stated periods, if possible, and when boilers are operating at low rating as at noontime and just before peak loads. Avoid holes in fire and excessive draft while burning out the fire. Clean fires as rapidly as possible to minimize cold air in the boiler. Do not fire too heavily immediately after cleaning. Do not pile hot ashes and clinkers against boiler front, use care in quenching and remove ashes as soon as possible.

C-278. Banking Fire. Do not bank fires any more than necessary. When fires are banked, make sure that a continuous light current of air is passed through the boiler. This is usually accomplished by having the ashpit doors closed, the firing doors slightly opened and the back damper perforated or nearly closed.

HANDLING BOILERS IN SERVICE

C-279. Water Level. The most important rule in the safe operation of boilers is to keep water in the boiler and as constantly at the proper level as conditions will permit. Never depend upon automatic alarms or feedwater regulators. Any inattention, other duties or reliance upon automatic devices cannot be accepted as an excuse for a boiler damaged by low water level.

C-280. The first duty on entering the boiler room is to ascertain whether the valves and connections between the boiler and water column are free and open especially when starting up in the morning after the fires have been banked over night. Then blow down the water column, noting the return of the water in the glass, and try the gage cocks until sure of the water level. This should be done at the beginning and end of each shift and also several times during the shift. Have the water column well lighted and keep the water glass clean. Do not allow steam to leak from the water column or its connections, as this will cause the water glass to show a false level.

C-281. If the level of the water is not visible in the water glass, try the gage cocks to determine whether the level of the water is above or below the water glass. If the level is below the water glass, stop the supply of fuel immediately and then the supply of air; close the dampers and ashpit doors. Close the feedwater valve and under no circumstances feedwater into the boiler. Haul the fire and, in the case of stokers or chain grates, keep them in motion with the fire doors open. Do not throw water on th

fire with fire or other hose. Do not open the safety valve or change the steam outlet valves or make any changes that will cause a sudden change in the stresses acting upon the boiler. Examine the bottom blow-off valves and repair them if they are found defective. Find the cause of the failure of the supply of water.

C-282. Foaming and Priming. If foaming occurs check the fuel supply and close the steam outlet valve long enough to determine the true level of the water in the glass. If the level of the water in the water glass is sufficiently high, blow down some of the water in the boiler and feed in fresh water. Use surface blow-off if any are installed. Repeat the alternate blowing-off and feeding several times, and if the foaming does not stop, draw the fire and continue the alternate blowing-off and feeding. When the boiler is sufficiently cooled off, empty the boiler and look for the cause of the foaming which may be caused by oil or other foreign matter in the feedwater or by scale solvent. Test safety valve and connections of water column and water glass for any choking or sticking. Determine positively the cause of foaming and adopt measures to prevent its recurrence.

C-283. Oil in Boiler. Watch carefully for any signs of oil in the feedwater heaters, water glasses and blowdowns. If a boiler becomes coated with oil or grease, shut down the boiler and clean it thoroughly. If the amount of oil is considerable, boil out in accordance with Par. C-311.

C-284. Feedwater Treatment. Execute carefully all instructions given for the treatment of feed water in your particular boiler room. Do not experiment with "home made" treatments or boiler compounds, unless advised to do so by a chemist experienced in feedwater treatment.

C-285. Blowing Off. Except where the amount and frequency of blowing down is determined by chemical analysis, blow down at least one gage every twenty-four hours. The amount of blowdown depends upon the number of hours per day the boiler is in service, the rate at which it operates and the kind of feedwater used. Blow down the boilers at a period in the day when the circulation of water in the boiler is slowest. Always open the cock first and the valve second; in closing, close the valve first and the cock second. Always open and close the blow-off valves carefully and slowly; if unusual effort is necessary to close the valve or cock, do not try to force them shut but empty the boiler and find the cause. In blowing down, open the cock or valve until it is half open and leave in that position until the water is blown down about $\frac{1}{2}$ in. in the water glass; then open the cock or valve wide open until the blowing off is completed. See that the valve shuts tight and remains tight. Repair all leaky blow-offs as soon as discovered. Use the surface blow-off frequently for a short period of time.

C-286. Where the water glass is not in view of operator blowing down a boiler, another operator shall be stationed where he can see the water glass and signal to the operator who is blowing down the boiler.

C-287. Leaks. When small leaks occur, locate their source and repair them as soon as boiler can be removed from service. If a serious leak occurs such as a leak along the longitudinal seams, shut down the boiler immediately by gradually reducing the steam pressure and have the boiler examined by an authorized inspector.

C-288. Repairs. Do not make any repairs upon a boiler, piping or auxiliaries while they are under steam pressure. Calking of pipes and joints and setting up of nuts and bolts under pressure to stop leakage must be prohibited.

C-289. Removal of Soot and Ashes. Soot should be dusted from the tubes once a day; whether a lance or soot blower is used, drain the steam or air-supply connections so that the steam or air is practically dry. Never use steam for dusting off tubes when the boiler is not under pressure. When a boiler is to be shut down, dust the tubes before the fire has died out and with the draft on after the boiler has been cooled, brush or scrape any hardened soot or deposit from the tubes.

C-290. Remove ashes frequently and do not permit the accumulation of any large amount of ashes in the ash pit, boilers, flues or base of stacks. Do not pile ashes against the furnace front and, when wetting down ashes, make sure that no water is thrown upon hot castings. Do not leave ashes banked about blow-off pipes as a protection.

C-291. When ashes are removed by a suction system, an explosion door shall be provided on the storage hopper. Where steam-jet ash conveyors are used, see that all operatives are warned against the water which may collect upon the top of the ashes in the hopper and may flow suddenly from the gate when the ashes are being removed. When necessary to bar through the gate to release clogged ashes, the operator shall be warned to stand sufficiently aside to avoid being burned by the hot ashes or water.

CARE OF APPLIANCES

C-292. Safety Valves. Test the safety valves at least once a day by gently raising the valve off the seat by hand or, when practicable, test the valves daily by raising the steam pressure to the blowing pressure of the safety valve. If the valve sticks do not try to release it by hammering; drop the pressure in the boiler and clean the valve seat or correct any other defect that may be found. Repair or replace leaking safety valves as soon as discovered.

C-293. When a safety valve blows, note the pressure on the boiler steam gage and, if the stipulated blowing pressure varies more than 5 lb. from the pressure noted on the gage, test the gage. If the gage is found correct, adjust the safety valve.

C-294. Do not permit setting or adjustment of safety valves by any one but a competent person. Do not have the water in boiler above the highest gage cock when setting or adjusting the valve. When the spring becomes weak and must be screwed down to secure the stipulated blowing pressure, make sure that the spring is not screwed down so far that there is a restriction of the proper amount of opening of the valve as called for in Pars. 282 and 284 of the Rules for the Construction of Power Boilers.

C-295. Do not open the safety valve to reduce the pressure in the case of low water in the boiler.

C-296. Never set the blowing point of a safety valve above the authorized pressure of the boiler.

C-297. When making a hydrostatic test do not try to hold the safety valve closed by screwing down the spring; blank the valve, clamp the seat in place or use some other suitable method. Make sure that the safety valve is placed in good working condition after the hydrostatic test has been made.

C-298. Keep scale, dirt or other foreign matter from collecting between the coils of the spring. When running a wire in the drain hole in the escape pipe to ascertain if it is clear, be careful that the wire does not move scale that may fall over the drain opening when the wire is removed.

C-299. Steam Pressure Gage. Blow down the gage connections frequently and especially when checking the safety valve, raising steam in a boiler and when foaming occurs.

C-300. Water Glass. When a water glass has broken, remove the broken pieces and, with head turned away from the water column, slowly open the bottom valve to blow out any remaining pieces. Before inserting the new glass, see that the glass is of the exact length required and that the connections are in line. Insert the glass and set up the stuffing-box nuts taking care not to set them up too tight. Then warm the glass by opening the drain cock of the glass and with head turned aside, open the top valve slightly and let a small current of steam flow through the glass. Close the drain cock after the glass is sufficiently warmed, open the bottom valve slightly and when the level of the water in the glass has become stable, open the bottom valve wide and then open the top valve wide, all the while keeping the face turned to one side.

C-301. Water glasses must be kept clean. Do not clean a glass with waste or linty cloth; use cloth, free from lint and dirt, wound about a wooden stick. Do not use a metal rod that would scratch the glass and start a crack.

HANDLING BOILERS OUT OF SERVICE

C-302. Cutting Out. To cut out a boiler, first cut off the supply of fuel. In a coal-fired boiler close ashpit and fire doors and close dampers. In an oil-fired boiler, continue the air supply until any oil on the floor of the combustion chamber is consumed and the gas passages are well ventilated; then close dampers. After the boiler ceases to require feed water and the non-return check valve, if any, on the steam line has closed, close the main steam stop valve. When possible blow off the tubes before the fire has died out. Fill the boiler to three-fourths of a glass.

C-303. Cooling Off. After the fires have died out, close all doors and open dampers. When the pressure has dropped to blowing down pressure (see Par. C-304), clean the furnace of all coal and ashes and permit the brickwork to cool for not less than two hours. When there is much sediment in the boiler, longer time must be allowed.

C-304. Emptying. After cooling off the setting, open the blow-off valves when the pressure in the boiler has been reduced to about 10 lb. if it is not feasible to empty the boiler at atmospheric pressure. When the boiler to be emptied is set in a battery, make sure the blow-off valves that are opened are on the boiler which is to be emptied. As soon as the boiler is empty, remove the manhole plates and covers of other openings.

C-305. Cleaning. Examine boiler frequently to determine how often the boiler should be washed. Wash more frequently when the boiler runs longer hours per day or at higher ratings, when feed water becomes foul or when scale solvents throw down scale.

C-306. Remove manhole and handhole plates, close feed valves, steam outlet valves and blow-off valves and hang sign on boiler to indicate that a man is working inside.

C-307. Use hose with considerable force or hand tools, if necessary, to remove scale. Disconnect blow-off pipe close to the boiler and run the water to waste. Horizontal-tubular boilers should be washed from below as well as from above. See that the water does not get on the brickwork of the combustion chamber.

C-308. After washing the boiler pass a light inside and see that the cleaning has been thorough and that no tools are left inside. If the boiler has been treated with kerosene in the feed water, ventilate the boiler; do not use a naked flame to examine the boiler.

C-309. Do not remove scale with kerosene if it can be done by any other means. If it is used, see that the boiler is dry and cool. Do not use kerosene in large quantities in a room where other boilers are in service unless special precautions are taken to keep the vapors from escaping into the boiler-room. Keep all lights away from the boiler except incandescent lamps enclosed in moisture-proof globes and guards.

C-310. Spray the inside of the boiler and, after allowing it to stand a sufficient length of time, wash thoroughly with hose and copious amount of water. Do not enter the boiler until it has been thoroughly ventilated. Also ventilate the boiler before entering it the next time that it is opened.

C-311. When boiler has been allowed to become heavily scaled or coated with oil it may be cleaned by boiling out with soda ash and kerosene. Fill boiler well above water line with water containing 50 lb. of soda ash and 5 gallons of kerosene to 1000 gallons of water. Close the boiler and start light fire sufficient to carry about 5 lb. pressure in the boiler. Continue boiling for two or three days, empty the boiler, then wash thoroughly and ventilate the boiler. Use the usual precaution against oil vapors.

C-312. When cleaning scale from tubes with mechanical hammer or cleaner follow the instructions given in Par. C-185.

C-313. Laying-Up. When laying-up a boiler for an extended period of time, follow the instructions given in Pars. C-152 to C-155, inclusive.

Second Revision of A.S.M.E. Boiler Code, 1923

A HEARING is held by the Boiler Code Committee at least once in four years, at which all interested parties may be heard, in order that such revisions may be made as are found to be desirable, as the state of the art advances. The year 1922 became the period of the second revision and the Boiler Code Committee held a Public Hearing in connection with the recent Annual Meeting of the Society in December, 1922, to which the membership of the Society and every one interested in the steam-boiler industry was invited to come and present their views.

For the convenience of every one interested, a printed schedule of the various proposed revisions had been published and distributed to all those who were invited to attend the Public Hearing and the opportunity was given thereat for the most careful consideration of all of the proposed revisions. As a result of the suggestions received at the Public Hearing, a number of modifications of the previously announced revisions were offered and in addition suggestions were received for still further revisions of the Code. All of these suggestions for modifications and new revisions have been carefully considered by the Boiler Code Committee and the result in modifications of revisions and additional revisions are here published.

It is the request of the Committee that these revisions be fully and freely discussed so that it may be possible for any one to suggest changes before the rules are brought to final form and presented to the Council for approval. Discussions should be mailed to C. W. Obert, Secretary of the Boiler Code Committee, 29 West 39th St., New York, N. Y., in order that they may be considered by the Boiler Code Committee.

The revisions here published are limited to the paragraphs appearing in the 1918 Edition of the A.S.M.E. Boiler Code, and the paragraph numbers refer to the paragraphs of similar number in that edition. For the convenience of the reader in studying the revisions, all added matter appears in small capitals and all deleted matter in smaller type in brackets.

In addition, there are here presented the revisions of the material specifications that have been approved by the Boiler Code Committee, to replace the specifications in the present edition of the Code, Pars. 23–178.

Modifications of Revisions

PAR. 250. REVISE FIRST TWO SENTENCES OF FORM GIVEN IN DECEMBER, 1922, ISSUE OF MECHANICAL ENGINEERING AS FOLLOWS:

250. A fire-tube boiler with tubes under 5 in. diameter shall have the ends of the tubes firmly rolled and beaded, or rolled, BEADED and welded at the firebox or combustion-chamber end, and rolled and beaded at the other end. In the case of tubes under $1^1/_2$ [$1^1/_4$] in. diameter, THEY [tubes] may be expanded by the Prosser method in place of rolling.

PAR. 308. ADD THE FOLLOWING TO THE REVISED FORM GIVEN IN THE JULY, 1922, ISSUE OF MECHANICAL ENGINEERING:

FOR PRESSURES NOT IN EXCESS OF 100 LB., RETURN CONNECTIONS OF THE SAME SIZE OR LARGER THAN THE SIZE HEREIN SPECIFIED MAY BE USED, AND TO WHICH THE BLOW-OFF MAY BE CONNECTED. IN SUCH CASE THE BLOW-OFF MUST BE SO LOCATED THAT THE CONNECTION MAY BE COMPLETELY DRAINED.

PAR. 318. ADD THE FOLLOWING TO THE REVISED FORM GIVEN IN THE AUGUST, 1922, ISSUE OF MECHANICAL ENGINEERING:

ON BOILERS HAVING MORE THAN 100 SQ. FT. OF HEATING SURFACE, THE FEED PIPE SHALL BE NOT LESS THAN $^3/_4$ IN. IN DIAMETER.

New Revisions

PAR. 301. REVISED:

Each steam-discharge outlet [over 2 in. in diameter] except safety-valve and superheater connections, shall be fitted with a stop valve [or valves of the outside-screw and yoke type], located as near the boiler as practicable. WHEN SUCH OUTLETS ARE OVER 2 IN. PIPE SIZE, THE VALVE OR VALVES USED ON THE CONNECTION SHALL BE OF THE OUTSIDE-SCREW AND YOKE TYPE.

MATERIAL SPECIFICATIONS

GENERAL RULES FOR INSPECTION AND TESTS

S-1. Inspection. At all times, while work on the contract of the purchaser is being performed, the inspector, representing the

purchaser, shall have free entry to all parts of the manufacturer's works which concern the manufacture of the material ordered. The manufacturer shall afford the inspector, without charge, all reasonable facilities to satisfy him that the material is being furnished in accordance with the specifications. Unless otherwise specified, all tests (except check analyses) and inspection shall be made at the place of manufacture, prior to shipment, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

S-2. Rejections. *a* Rejections based on tests made by the purchaser under the provisions of the specifications shall be reported to the manufacturer within five working days from the receipt of samples.

b Material which shows injurious defects subsequent to its acceptance at the manufacturer's works will be rejected, and the manufacturer shall be notified.

S-3. Rehearing. Samples which represent rejected material, tested by the purchaser under the provisions of these rules, shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

S-4. Ladle Analyses. *a* The manufacturer shall make an analysis of each melt of steel, from a test ingot taken during the pouring of the melts, to determine the percentage of carbon, manganese, phosphorus, and sulphur. The results of analysis shall conform to requirements, and shall be reported to the purchaser, or his representative.

Check Analyses. *b* The purchaser may make an analysis from finished material representing each melt. The chemical composition thus determined shall conform to the requirements.

Physical Tests. *c* The yield point shall be determined by the drop of the beam of the testing machine. For determination of the yield point the speed of the crosshead of the machine shall not exceed $\frac{1}{2}$ in. per minute when the elongation is taken in 2 in., nor exceed 2 in. per minute when the elongation is taken in 8 in. After the yield point has been passed the speed of the machine may be increased to not more than 2 in. per minute when the elongation is taken in 2 in., nor more than 6 in. per minute when the elongation is taken in 8 in.

SPECIFICATIONS FOR STEEL BOILER PLATE

NOTE: This specification is printed merely for information and is not in its final approved form. The Boiler Code Committee feels that additional protection should be secured in the case of firebox steel and has suggested to the American Society for Testing Materials and the Association of American Steel Manufacturers that an additional chemical check analysis from the top of the plate and possibly an additional tensile test also from the top of the plate should be provided for this class of steel. The replies of these organizations have not been received and the final form that this specification will take will depend upon the actions of these associations.

S-5. Classes. These specifications cover two classes of steel for boilers, namely: FLANGE and FIREBOX.

S-6. Process. The steel shall be made by the open-hearth process.

S-7. Chemical Composition. The steel shall conform to the following requirements as to chemical composition.

		Flange	Firebox
Carbon	Plates $\frac{3}{4}$ in. thick or under	not over 0.25 per cent	
	Plates over $\frac{3}{4}$ in. thick	not over 0.30 per cent	
Manganese	Plates $\frac{3}{4}$ in. thick or under	0.30–0.60	0.30–0.50
	Plates over $\frac{3}{4}$ in. thick	0.30–0.60	0.30–0.60
Phosphorus	Acid	Not over 0.05 per cent	Not over 0.04 per cent
	Basic	Not over 0.04 per cent	Not over 0.035 per cent
Sulphur		Not over 0.05 per cent	Not over 0.04 per cent

S-8. Check Analyses. As a substitute for check analyses in the general rules, the purchaser may make an analysis from a broken tension-test specimen representing each plate as rolled. The chemical composition thus determined shall conform to the requirements. For firebox steel, the purchaser may also make an analysis from a bend-test specimen representing each plate as rolled. The chemical composition thus determined shall not exceed the requirements by more than 10 per cent.

S-9. Tension Tests. *a* The material shall conform to the following requirements as to tensile properties:

	Flange	Firebox
Tensile strength, lb. per sq. in.	55,000–65,000	55,000–65,000
Yield point, min., lb. per sq. in.	0.5 tens. str.	0.5 tens. str.
Elongation in 8 in., min. per cent	$\frac{1,500,000}{\text{Tens. str.}}$	$\frac{1,550,000}{\text{Tens. str.}}$
(See Par. S-10*a*)		

b Should the above rule for minimum allowable elongation give a value less than 25 per cent for firebox steel, the minimum allowable elongation shall be taken as 25 per cent, subject to the modification given.

c The tensile strength of the test specimen taken longitudinally from the top of the plate for firebox steel shall not exceed 70,000 lb. per sq. in.

S-10. Modifications in Elongation. *a* For material over $\frac{3}{4}$ in. in thickness, a deduction from the percentages of elongation specified of 0.125 per cent shall be made for each increase of $\frac{1}{32}$ in. of the specified thickness above $\frac{3}{4}$ in. to a minimum of 20 per cent.

b For material $\frac{1}{4}$ in. in thickness, the elongation shall be measured on a gage length of 6 in.

S-11. Bend Test. The bend-test specimen shall bend cold through 180 deg. without cracking on the outside of the bent portion, as follows: For material 1 in. or under in thickness, around a pin the diameter of which is equal to the thickness of the specimen; and for material over 1 in. in thickness, around a pin the diameter of which is equal to twice the thickness of the specimen.

S-12. Homogeneity Tests. For firebox steel, a sample taken from a broken tension-test specimen shall not show any single seam or cavity more than $\frac{1}{4}$ in. long in either of the three fractures obtained in the test for homogeneity, which shall be made as follows:

The specimen shall be either nicked with a chisel or grooved on a machine, transversely, about $\frac{1}{16}$ in. deep, in three places about 2 in. apart. The first groove shall be made 2 in. from the square end; each succeeding groove shall be made on the opposite side from the preceding one. The specimen shall then be firmly held in a vise, with the first groove about $\frac{1}{4}$ in. above the jaws, and the projecting end broken off by light blows of a hammer, the bending being away from the groove. The specimen shall be broken at the other two grooves in the same manner. The object of this test is to open and render visible to the eye any seams due to failure to weld or to interposed foreign matter, or any cavities due to gas bubbles in the ingot. One side of each fracture shall be examined and the length of the seams and cavities determined, a pocket lens being used if necessary.

S-13. Test Specimens. *a* Tension-test specimens shall be taken longitudinally from the bottom of the finished rolled material, and bend-test specimens shall be taken transversely from the middle of the top of the finished rolled material. The longitudinal test specimen shall be taken in the direction of the longitudinal axis of the ingot, and the transverse-test specimen at right angles to that axis. For firebox steel, an additional tension-test specimen shall be taken longitudinally from a top corner of the finished rolled material.

b Tension- and bend-test specimens shall be of the full thickness of material as rolled, and shall be machined to the form and dimensions shown in Fig. 1; except that bend-test specimens may be machined with both edges parallel.

(Fig. 1, A.S.M.E. Code [1918], page 13, to be inserted.)

S-14. Number of Tests. *a* One tension- and one bend-test shall be made from each plate as rolled. For firebox steel an additional tension test will be made from the top of the plate. Tensile strength only will be determined from this specimen.

b If any test specimen shows defective machining or develops flaws, it may be discarded and another specimen substituted.

c If the percentage of elongation of any tension-test specimen is less than that specified and any part of the fracture is outside the middle third of the gaged length, as indicated by the scribe scratches marked on the specimen before testing, a retest shall be allowed.

S-15. Permissible Variation. The thickness of each plate shall not vary under the gage specified more than 0.01 in. (The overweight limits are considered a matter of contract between the steel manufacturer and the boiler builder.)

S-16. Finish. The finished material shall be free from injurious defects and shall have a workmanlike finish.

S-17. Marking. *a* The name or brand of the manufacturer, the manufacturer's test identification number, class and lowest

tensile strength specified shall be legibly stamped on each finished plate in two places not less than 12 in. from the edges and on each butt strap near the center line not less than 12 in. from each end. Manufacturer's test identification number shall be legibly stamped on each test specimen.

SPECIFICATIONS FOR STEEL BOILER RIVETS

NOTE: This specification has not been approved by the Boiler Code Committee and is not in its final form, being printed for information only. An agreement has not been reached with the manufacturers of boiler rivets in regard to the tolerances for finished rivets. The tolerances as given in the specifications printed herewith are those which the Boiler Code Committee believe are reasonable. Some objections have, however, been raised to these tolerances by rivet manufacturers, and the Boiler Code Committee will take no final action on this specification until an agreement is reached as to what reasonable tolerances for the finished rivets should be.

A—REQUIREMENTS FOR ROLLED BARS

S-18. Process. The steel shall be made by the open-hearth process.

S-19. Chemical Composition. The steel shall conform to the following requirements as to chemical composition:

Manganese	0.30–0.50 per cent
Phosphorus	not over 0.04 per cent
Sulphur	not over 0.045 per cent

S-20. Tension Tests. The bars shall conform to the following requirements as to tensile properties:

Tensile strength, lb. per sq. in.	45,000–55,000
Yield point, min., lb. per sq. in.	0.5 Tens. Str.
Elongation in 8 in., min., per cent but need not exceed 30 per cent	1,500,000 / Tens. Str.

S-21. Bend Tests. a Cold-Bend Tests. The test specimen shall bend cold through 180 deg. flat on itself without cracking on the outside of the bent portion.

b Quench-Bend Tests. The test specimen, when heated to a light cherry red as seen in the dark (not less than 1200 deg. fahr.), and quenched at once in water the temperature of which is between 80 deg. and 90 deg. fahr., shall bend through 180 deg. flat on itself without cracking on the outside of the bent portion.

S-22. Test Specimens. Test specimens shall be of the section of the bars as rolled. Tension- and bend-test specimens for rivet bars which have been cold-drawn shall be normalized before testing.

S-23. Number of Tests. a Two tension, two cold-bend, and two quench-bend tests shall be made from each melt, each of which shall conform to the requirements specified.

b If any test specimen develops flaws, it may be discarded and another specimen substituted.

c If the percentage of elongation of any tension-test specimen is less than that specified and any part of the fracture is outside the middle third of the gaged length, as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed.

S-24. Permissible Variation in Gage. The diameter of each bar shall not vary from that specified more than the amount given in the following table:

Diameters, In.	Variation in Diameter Under, In.	Variation in Diameter Over, In.	Out of Round In.
Up to 1 1/2, inclusive	0.007	0.007	0.010
Over 1 1/2 to 1, inclusive	0.010	0.010	0.013
Over 1 to 1 1/4, inclusive	0.012	0.012	0.016
Over 1 1/4 to 1 1/2, inclusive	0.015	0.015	0.021
Over 1 1/2 to 2, inclusive	0.022	0.022	0.023

S-25. Finish. The finished bars shall be free from injurious defects and shall have a workmanlike finish.

S-26. Marking. Rivet bars shall, when loaded for shipment, be properly separated and marked with the name or brand of the manufacturer and the melt number for identification. The melt number shall be legibly marked on each test specimen.

B—REQUIREMENTS FOR RIVETS

S-27. Bend Tests. The rivet shank shall bend cold through 180 deg. flat on itself, as shown in Fig. 2, without cracking on the outside of the bent portion.

S-28. Flattening Tests. a The rivet head shall flatten, while hot, to a diameter 2 1/2 times the diameter of the shank, as shown in Fig. 3, without cracking at the edges.

b Three bend and three flattening tests shall be made from each size in each lot of rivets offered for inspection, each of which shall conform to the requirements specified.

(Figs. 2 and 3, A.S.M.E. Code [1918], page 18, to be inserted here.)

S-29. Permissible Tolerances. The diameter of the shank of finished rivets measured at any point between the fillet under the head and a point two-thirds of the length from the head to the end of the shank, shall not vary from the nominal diameter more than the amount given in the following table:

Diameters, In.	Variation in Diameter Under, In.	Variation in Diameter Over, In.	Out of Round In.
Up to 1 1/2, inclusive	0.022	0.007	0.010
Over 1 1/2 to 1, inclusive	0.025	0.010	0.013
Over 1 to 1 1/4, inclusive	0.027	0.012	0.016
Over 1 1/4 to 1 1/2, inclusive	0.030	0.015	0.021
Over 1 1/2 to 2, inclusive	0.037	0.022	0.023

The dimensions of the rivet head shall not vary more than two per cent over or under, from those specified.

SPECIFICATIONS FOR STEEL STAYBOLTS

S-30. Solid or Hollow Staybolts. Steel for solid or hollow staybolts shall conform to the requirements for Boiler Rivet Steel specified, except that the tensile properties shall be as follows:

Tensile strength, lb. per sq. in.	50,000–60,000
Yield point, min., lb. per sq. in.	0.5 Tens. Str.
Elongation in 8 in., min., per cent	1,500,000 / Tens. Str.

The permissible variations in gage shall be as given in Par. S-32.

S-31. Seamless Tubing for Staybolts. a Seamless steel tubing for threaded steel staybolts shall conform to the requirements for Boiler Rivet Steel specified, with the exceptions as given herewith. This specification will not apply to stay tubes for locomotive boilers.

Chemical Composition. b The chemical composition shall conform to the requirements for Seamless Steel Tubes.

Physical Requirements. c The physical requirements shall be as follows:

Tensile strength, lb. per sq. in., minimum	48,000
Yield point, min., lb. per sq. in.	25,000
Elongation in 8 in., min., per cent	1,500,000 / Tens. Str.

Tests. d Two tests from each 2500 feet of tubing may be made in absence of tests from each melt.

To insure sound and fine-grained structure, a special fracture test shall be made from at least each 2500 feet of tubing by cutting partly through the wall of the tube and breaking it off when removing the crop end. The fracture thus produced shall be fine-grained. This test will be used in place of the cold and hot quench bend tests specified.

e Ladle analysis will not be required.

f The marking requirement for rivet bars will not be required.

S-32. Permissible Variations in Gage. Solid or hollow bars for staybolts, not exceeding 1 1/4 in. diameter, which are to be threaded as rolled, shall be truly round within 0.01 in. and shall not vary more than 0.005 in. under or more than 0.01 in. over. All other bars for staybolts shall conform to the specified tolerances for Rivet Bars.

SPECIFICATIONS FOR STEEL BARS

S-33. Process. The steel shall be made by the open-hearth process.

S-34. Chemical Composition. The steel shall conform to the following requirements as to chemical composition:

Phosphorus	Acid	Not over 0.05 per cent
	Basic	Not over 0.04 per cent
Sulphur		Not over 0.05 per cent

S-35. Tension Tests. a The material shall conform to the following requirements as to tensile properties:

Tensile strength, lb. per sq. in.	55,000–65,000
Yield point, min. per sq. in.	0.5 Tens. Str.
Elongation in 8-in., min. per cent	1,500,000 / Tens. Str.
Elongation in 2-in., min., per cent	26

S-36. Modifications in Elongation. For material over 3/4 in. in thickness, a deduction from the percentages of elongation specified of 0.125 per cent shall be made for each increase of 1/32 in. of the specified thickness above 3/4 in.

S-37. Bend Tests. *a* Test specimen shall bend cold through 180 deg. without cracking on the outside of the bent portion, except as specified in section *b*, as follows: For material 1 in. or under in thickness or diameter flat on itself; for material over 1 in. to and including 1 1/2 in. in thickness or diameter around a pin the diameter of which is equal to the thickness or the diameter of the specimen; and for material over 1 1/2 in. in thickness or diameter around a pin the diameter of which is equal to twice the thickness or diameter of the specimen.

b The 1-in. by 1/2-in. test specimen for bars over 1 1/2 in. in thickness or diameter shall bend cold through 180 deg. around a 1/2-in. pin without cracking on the outside of the bent portion.

S-38. Test Specimens. *a* Test specimens shall be of the full thickness or diameter of material as rolled, except as specified in sections *b* and *c*.

b Test specimens for shapes and flats may be machined to the form and dimensions shown in Fig. 1, or with both edges parallel.

c Test specimens for bars over 1 1/2 in. in thickness or diameter may be machined to a thickness or diameter of at least 3/4 in. for a length of at least 9 in.; or tension-test specimens may conform to the dimensions shown in Fig. 4. Bend-test specimens may be 1 in. by 1/2 in. in section.

S-39. Number of Tests. *a* One tension and one bend test shall be made from each melt; except that if material from one melt differs 3/8 in. or more in thickness, one tension and one bend test shall be made from both the thickest and the thinnest material rolled.

b If any test specimen shows defective machining or develops flaws, it may be discarded and another specimen substituted.

c If the percentage of elongation of any tension-test specimen is less than that specified and any part of the fracture is more than 3/4 in. from the center of the gage length of a 2-in. specimen or is outside the middle third of the gage length of an 8-in. specimen, as indicated by scribe scratches marked on the specimen before testing a retest shall be allowed.

S-40. Permissible Variation in Gage. The diameter of each bar shall not vary from that specified more than the amount given in the following table:

Diameters, In.	Variation in Diameter Under, In.	Variation in Diameter Over, In.	Out of Round In.
Up to 1/2, inclusive	0.007	0.007	0.010
Over 1/2 to 1, inclusive	0.010	0.010	0.013
Over 1 to 1 1/4, inclusive	0.012	0.012	0.016
Over 1 1/4 to 1 1/2, inclusive	0.015	0.015	0.021
Over 1 1/2 to 2, inclusive	0.022	0.022	0.023
Over 2 to 2 1/2, inclusive	1/64	3/64	0.023
Over 2 1/2 to 3, inclusive	1/32	3/64	0.035

S-41. Finish. The finished material shall be free from injurious defects and shall have a workmanlike finish.

S-42. Marking. Bars shall, when loaded for shipment, be properly separated, and marked with the name or brand of the manufacturer and melt number for identification. The melt number shall be legibly marked on each test specimen.

SPECIFICATIONS FOR STEEL CASTINGS

S-43. Material Covered. These specifications cover two classes of castings, namely:

Class A, ordinary castings for which no physical requirements are specified;

Class B, castings for which physical requirements are specified.

S-44. Process. The steel shall be made by one or more of the following processes: open-hearth, electric-furnace, side-blow converter or crucible.

S-45. Heat Treatment. *a* Class A castings need not be annealed unless so specified, or unless the carbon content exceeds 0.30 per cent.

b Class B, castings shall be properly annealed, the treatment depending upon the design and chemical composition of the castings.

S-46. Chemical Composition. The castings shall conform to the following requirements as to chemical composition:

		Class A	Class B
Carbon		Not over 0.45 per cent	
Phosphorus	Acid	Not over 0.07 per cent	
	Basic	Not over 0.06 per cent	Not over 0.05 per cent
Sulphur			Not over 0.05 per cent

(For Class B Castings Only.)

S-47. Tension Tests. *a* The castings shall conform to the following minimum requirements as to tensile properties:

Yield point, lb. per sq. in.	29,250
Elongation in 2-in., per cent	1,600,000
	Tens. Str.
Elongation in 2-in., per cent—not less than	24
Reduction of area per cent	2,600,000
	Tens. Str.
Reduction of area per cent—not less than	35

The tensile strength shall be reported as information.

S-48. Alternative Tests to Destruction. In the case of orders including only castings not exceeding 150 lb. in weight, a test to destruction of one casting from each 100 castings or smaller lot may be substituted for the tension tests, at the option of the inspector. This test shall show the material to be ductile, free from injurious defects, and suitable for the purpose intended.

S-49. Test Specimens. *a* Tension-test specimens shall be taken from test bars cast attached to the castings where practicable. If the design of the castings is such that test bars should not be attached to the castings, the test bars shall be cast attached to special blocks of which a sufficient number shall be provided for each lot of castings. Test bars from which tension-test specimens are to be taken shall remain attached to the castings or blocks they represent through heat treatment and until presented for inspection. Test bars shall be provided in sufficient numbers to furnish the tests required.

b If satisfactory to the manufacturer and inspector, tension-test specimens may be cut from heat-treated castings instead of from test bars.

c Tension-test specimens shall conform to dimensions shown in Fig. —. The ends shall be of a form to fit the holders of the testing machine in such a way that the load shall be axial.

d Bend-test specimens shall be machined to 1 in. by 1/2 in. in section with corners rounded to a radius not over 1/16 in.

S-50. Number of Tests. *a* One tension test shall be made from each melt in each treatment charge, and from each casting weighing 500 lb. or over when specified.

b If any test specimen shows defective machining or develops flaws, it may be discarded; in which case another specimen from the same lot shall be substituted.

c If the percentage of elongation of any tension-test specimen is less than that specified and any part of the fracture is more than 3/4 in. from the center of the gage length, as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed.

S-51. Retreatment. If the results of the physical test for any lot do not meet the requirements specified, such lot may be retreated, but not more than twice. Retest shall be made as specified.

S-52. Workmanship. Castings shall conform substantially to the shapes and sizes indicated by the patterns and drawings submitted by the purchaser.

S-53. Finish Welding. *a* Castings shall be free from injurious defects.

b Defects which do not impair the strength of the castings may be welded by an approved process. The defect shall be cleaned out to solid metal, before welding, and when so required by the inspector, shall be submitted to him in this condition for his approval. When required by the inspector, important castings shall be heat treated after welding.

SPECIFICATIONS FOR BOILER RIVET, STAYBOLT, AND REFINED BAR IRON

S-54. Process. The iron shall be rolled from a bloom, slab pile, or box pile made wholly from reworked all-pig puddled iron or reworked knobbled charcoal iron. For rivet and staybolt iron the puddle mixture and the component parts of the bloom, slab pile

or box pile shall be free from any admixture of iron scrap or steel. Staybolt iron shall be double worked, i.e., twice piled.

S-55. Physical Properties and Tests. *a* The iron shall conform to the following requirements as to tensile properties:

	Rivet Iron	Staybolt Iron	Bar Iron
Tensile strength, lb. per sq. in., not over	52,000	52,000	53,000
Yield point, lb. per sq. in., not less than	28,000	29,000	28,000
Elongation in 8 in., not less than, Round Section	28 per cent	30 per cent	25 per cent
Reduction of area, not less than, Round Section	45 per cent	48 per cent	40 per cent

S-56. Cold-Bend Tests. Rivet Iron. *a* The test specimen shall withstand being bent cold through 180 deg. flat on itself, without fracture on the outside of the bent portion.

Staybolt Iron. *b* The test specimen shall withstand being bent cold through 180 deg. flat on itself in both directions, without fracture on the outside of the bent portions.

Bar Iron. *c* The test specimen shall withstand being bent cold through 180 deg. without fracture on the outside of the bent portion, around a pin the diameter of which is not greater than one-half the square of the thickness or diameter of the specimen.

S-57. Nick-Bend Tests. The test specimen when nicked 25 per cent around for round bars, and along one side for flat bars, with a tool having a 60 deg. cutting edge, to a depth of not less than 8 per cent or more than 16 per cent of the diameter or thickness of the specimen, and broken, shall show a wholly fibrous fracture.

Bend tests may be made by pressure or by blows.

S-58. Etch Tests. The cross-section of the test specimen shall be ground or polished, and etched for a sufficient period to develop the structure. For rivet and staybolt iron this test shall show the material to have been rolled from a bloom, slab pile or box pile and to be free from steel; for bar iron the structure shall be uniform and free from steel.

S-59. Test Specimens. Test specimens shall be of the full section of material as rolled.

S-60. Number of Tests. *a* All bars of a given grade and size shall be piled separately, sorted in lots of 100 each. Two bars shall be selected at random from each lot or fraction thereof and tested as specified; but only one of these bars shall be etch-tested.

b If any test specimen from bars originally selected to represent a lot of material contains surface defects not visible before testing but visible after testing, or if a tension-test specimen breaks outside the middle third of the gage length, the individual bar shall be rejected and one retest from a different bar will be allowed.

S-61. Permissible Variations in Gage. The diameter of each bar shall not vary from that specified more than the amount given in the following table:

Diameters, In.	Variations in Diameter, Under, In.	Variations in Diameter, Over, In.	Out of Round, In.
Up to 1/2, inclusive	0.007	0.007	0.010
Over 1/2 to 1, inclusive	0.010	0.010	0.013
Over 1 to 1 1/4, inclusive	0.012	0.012	0.016
Over 1 1/4 to 1 1/2, inclusive	0.015	0.015	0.021
Over 1 1/2 to 2, inclusive	0.022	0.022	0.023
Over 2 to 2 1/2, inclusive	1/64	3/64	0.023
Over 2 1/2 to 3, inclusive	1/32	3/64	0.035

The widths or thicknesses of flat bars shall not vary more than one per cent from that specified.

S-62. Finish. The bars shall be smoothly rolled and free from slivers, depressions, crop ends, seams and evidences of being burnt.

S-63. Marking. The bars shall be stamped or otherwise marked as designated by the purchaser.

SPECIFICATIONS FOR LAP-WELDED AND SEAMLESS STEEL AND LAP-WELDED IRON BOILER TUBES

Based upon A.S.T.M. Specifications A83–22T
(Comprises Pars. S-64–S-80)

SPECIFICATIONS FOR GRAY-IRON CASTINGS

Based upon A.S.T.M Specifications A48–18
(Comprises Pars. S-81–S-90)

SPECIFICATIONS FOR MALLEABLE CASTINGS

Based upon A.S.T.M. Specifications A47–19 Revised
(Comprises Pars. S-91–S-98)

SPECIFICATIONS FOR COPPER PLATES

Based upon A.S.T.M. Specifications B11–18
(Comprises Pars. S-99–S-109)

SPECIFICATIONS FOR COPPER BARS FOR STAYBOLTS

Based upon A.S.T.M Specifications B12–21
(Comprises Pars. S-110–S-120)

SPECIFICATIONS FOR SEAMLESS COPPER BOILER TUBES

Based upon A.S.T.M. Specifications B13–18
(Comprises Pars. S-121–S-136)

Recent Developments in Balancing Machines

(Continued from page 355)

its synchronous speed. The armature to be balanced is driven by the belt *O*. The critical speed of the apparatus is about 1700 r.p.m. The speed of the armature while operating is 10,000 r.p.m.

The operation of this balancing machine is as follows: The armature is mounted in the machine and the carriage *E* is moved so that the pointer *S* is in one of the transverse planes in which the unbalance is to be corrected. The treadle *R* is pressed down, thus closing the switch *P* and releasing the brake *Q*. The rotation of the armature produces vibrations of the bed around the fulcrum axis; the amplitude is a measure of the weight to be applied at

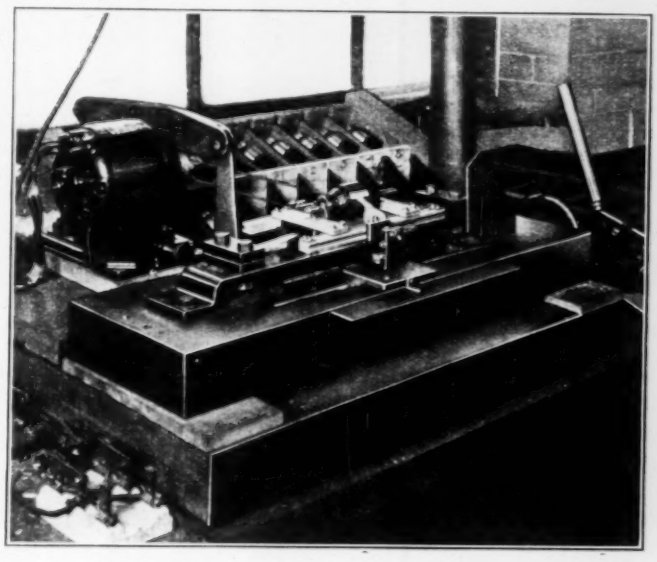

FIG. 6 BALANCING MACHINE SLIGHTLY MODIFIED

the other end of the armature. This weight is recorded by the vibrating reed. The treadle is then released, stopping the driving motor almost instantaneously. The recorded weight is applied at an arbitrary location and the armature is again rotated. The second amplitude will indicate if this arbitrary location is correct or not. Three to four trials usually locate the weight correctly. The carriage is then moved into the plane where the first weight was applied and the same procedure is repeated. The entire operation consumes but a few moments.

Fig. 6 shows the same machine slightly modified. The vibrating reed is attached to one end of the vibrating bed. As a result of this, the reed does not record the angular deflection of the bed in a uniform measure for all fulcrum locations. This variation was found to be negligible, however. The production of this machine is about 20 armatures per hour at the present time. It may be increased considerably as the operator gains in experience. The accuracy of the balancing result is ±0.00008 lb. at 3/4 in. radius, the two balancing planes being 1 in. apart.

Safety Code for Mechanical Power-Transmission Apparatus

A Code Now Proposed for General Adoption by the Industrial Accident Boards and Commissions of the Various States

In the November, 1920, issue of "Mechanical Engineering" the formation of a Sectional Committee to develop a national Safety Code for Mechanical Power-Transmission Apparatus was announced. This committee was organized under the Rules of Procedure of the American Engineering Standards Committee and has for its sponsors the International Association of Industrial Accident Boards and Commissions, The National Workmen's Compensation Service Bureau, and The American Society of Mechanical Engineers.

During the progress of the Sectional Committee's work a number of drafts of the code were prepared and passed upon by its 24 members. Later printed proofs were circulated to approximately 400 persons known to be interested in the development of this code. These included manufactures of this equipment, users of the equipment, and safety-code enforcement officers.

All the comments offered as a result of this circularization were carefully considered at a meeting of the full Sectional Committee and a revised draft of the code was subsequently prepared. This revised draft has now been formally presented to the three sponsor bodies for approval and adoption, actions which are obviously necessary before this safety code can be transmitted to the American Engineering Standards Committee for approval as a Tentative American Standard.

The following abstract of this code was prepared at the request of the A.S.M.E. Standing Committee on Safety Codes by Carl B. Auel, one of its members who is also one of that society's representatives on this Sectional Committee and is serving as its chairman.

THE Safety Code for Mechanical Power-Transmission Apparatus, as it now stands, is the result of a very considerable amount of study over a period of many months. The Committee did not rely alone upon the judgment of its members, but had as well the benefit of the advice and experience of many experts, who willingly placed themselves at the service of the Committee in various ways.

Following the trend of more recent efforts in safety work, the code is an endeavor to combine the best, both with respect to theory and to practice; and, where these seemed occasionally at variance, decision was reached only after careful consideration as to which should be followed.

It is therefore reasonable to assume that while the code, as time goes on, unquestionably will undergo modification and improvement, it nevertheless in its present form offers adequate protection to the workers in industry.

Scope

This code applies to all moving parts of equipment used in the mechanical transmission of power, including prime movers, intermediate equipment and driven machines, excluding point of operation.

Note: The safeguarding of all connecting rods, cranks, flywheels, shafting, spindles, pulleys, belts (except flat belts one (1) inch or less in width or round belts one-half ($\frac{1}{2}$) inch or less in diameter), link belts, chains, ropes and rope drives, gears, sprockets, friction drives, cams, couplings, clutches, counterweights, revolving or reciprocating parts, up to but not including point of operation, also all bolts, keys, set screws, oil cups or similar projections, shall be included in and be in accordance with the provisions of the Mechanical Power-Transmission Code.

Interpretations and Exceptions

The purpose of this code is to provide reasonable safety for life, limb, and health. It should be liberally construed and applied by enforcing authorities to secure these results and in cases of practical difficulty or unnecessary hardship, exceptions from the literal requirements may be granted so long as equivalent protection is secured. Where specific devices or methods are mentioned in this code, other devices or methods which will secure equally good results may be used, subject to the approval of the enforcing authority.

Definitions

In order to clarify the text, it is prefaced by definitions of a number of the terms used; as, for example, the term "exposed to contact" is "interpreted as meaning that the location of any object is such that a person is liable to come into contact with it and be injured."

The code itself is divided into six parts, each with suitable subdivisions. These parts have to do respectively with prime movers, mechanical power-transmission equipment, starting and stopping devices, guard standards, operating rules, and discussion.

Prime Movers

This part of the code is very brief and offers no complications in the carrying out of its requirements, concerning itself simply with the guarding of flywheels, cranks, connecting rods, tail rods, and governor balls. As will be observed in this section, and, in fact, largely throughout the code, alternative methods of guarding have been presented wherever possible.

Flywheels located so that any part is six (6) feet or less above floor or platform shall be guarded in one of the following ways:

(*a*) With an inclosure of sheet, perforated, or expanded metal or woven wire.

(*b*) With guard rails placed not less than fifteen (15) inches nor more than twenty (20) inches from rim. When flywheel extends into pit or is within 12 inches of floor a standard toe board shall also be provided.

(*c*) When the upper rim of flywheel protrudes through a working floor it shall be entirely enclosed or surrounded by a guard rail and toe board.

(*d*) For flywheels with smooth rims five (5) feet or less in diameter where the preceding methods cannot be applied, the following may be used: A disk attached to the flywheel in such manner as to cover the spokes of the wheel on the exposed side and present a smooth surface and edge, at the same time providing means for periodic inspection. An open space, not exceeding four (4) inches in width may be left between the outside edge of the disk and the rim of the wheel if desired, to facilitate turning the wheel over. Where a disk is used, the keys or other dangerous projections not covered by disk, shall be cut off or covered.

Note: This does not apply to flywheels with solid web centers.

(*e*) Adjustable guard to be used for starting engine or for running adjustment may be provided at the flywheel of gas or oil engines. A slot opening for jack bar will be permitted.

Cranks and connecting rods, when exposed to contact, shall be guarded in accordance with Part IV, Sections 40 and 41, or by a guard rail as described in Part IV, Rule 424.

Tail rods or extension piston rods shall be guarded in accordance with Part IV, Sections 40 and 42, or by a guard rail on sides and end, with a clearance of not less than fifteen (15) inches when rod is fully extended.

Governor balls six (6) feet or less from the floor or other working level, when exposed to contact, shall be provided with an enclosure extending to the top of the governor balls when at their highest position.

Mechanical Power-Transmission Equipment

As would be expected, this section, having to do with transmission equipment, constitutes the backbone of the code, shafting, pulleys, belts, ropes, gears, sprockets, chains, friction drives, keys and other projections, collars, couplings, and bearings, being treated in turn.

Shafting. Additional to the necessity of thoroughly guarding all exposed shafting when six feet or less from the floor or working platform, or unless at least fifteen feet above a driveway, particular emphasis is placed on the need for securing shafting, whether horizontal, vertical, or inclined, against excessive endwise movement.

Projecting shafting ends are not permitted, except when guarded by non-rotating caps or safety sleeves.

It is realized that the guarding of shafting in the regulation manner would involve an unnecessary expense if the rules were made universally mandatory. Exception has therefore been made in the case of shafting located in basements, used exclusively for power-transmission equipment, by the following provisions:

When belts, pulleys, and shafting are located in basements, towers, and rooms used exclusively for power-transmission equipment, the requirements for safeguarding may be waived if the following conditions are met:

1 The basement, tower, or room occupied by transmission equipment shall be locked against unauthorized entrance.

2 The vertical clearance in passageways between the floor and power-transmission beams, ceiling or any other objects, should not be less than five (5) feet six (6) inches.

3 The intensity of illumination shall conform to The American Engineering Standards Code for lighting of factories, mills, and other work places.

4 The footing shall be dry, firm, and level.

5 The route followed by the oiler shall be protected in such a manner as to prevent accident.

Pulleys. Pulleys are required to be guarded if any parts are six feet or less from the floor or working platform; but modification is made in this requirement when they serve as balance wheels, for example on punch presses, the code providing that:

Pulleys any part of which are six (6) feet or less from the floor or working platform shall be guarded in accordance with the standards specified under Part IV, Sections 40 and 42. Pulleys serving as balance wheels (e.g., punch presses) on which the point of contact between belt and pulley is more than six (6) feet from the floor or platform, may be guarded with a disk covering the spokes.

Guides are required to prevent belts leaving pulleys, unless the distance to the nearest fixed pulley, clutch, or hanger exceeds the width of the belt used. Overhanging pulleys, where there is no bearing between them and the outer end of the shafting, must be similarly provided with guides.

The use of pulleys with cracked or broken rims is forbidden, as in the use of composition or wood pulleys in locations where they would be subjected continually to the action of moisture.

Particular warning is given against operating pulleys at excessive speeds as follows:

Pulleys operating at a rim speed in excess of 4000 feet per minute shall be especially designed for the purpose and carefully balanced for the speed at which they are to operate.

Belts, Ropes, and Chain Drives. In the guarding of belts and ropes, the code states:

(a) Where both runs of horizontal belts are six (6) feet or less from the floor level, the guard shall extend to at least fifteen (15) inches above the belt or, to a standard height except that where both runs of a horizontal belt are 42 inches or less from the floor, the belt shall be fully enclosed in accordance with Part IV, Sections 40 and 42.

NOTE: In power plants or power-development rooms a guard rail may be used in lieu of the above.

(b) Overhead horizontal belts, with lower part seven (7) feet or less from the floor or platform, shall be guarded on sides and bottom.

(c) Horizontal overhead belts more than seven (7) feet above floor or platform shall be guarded for their entire length under the following conditions:

1 If located over passageways or work place and traveling 1800 feet or more per minute, and

2 If center to center distance between pulleys is ten (10) feet or more, and

3 If belt is eight (8) inches or more in width.

For exception in case of flat belts 1 inch or less in width or round belts ½ inch, or less in diameter, see "Scope."

(d) Where the upper and lower runs of horizontal belts are so located that passage of persons between them would be possible the passage shall be either:

1 Completely barred by a guard rail or other barrier in accordance with Part IV, Sections 40 and 42.

2 Where passage is regarded as necessary there shall be a platform over the lower run guarded on either side by a railing completely filled in with wire mesh or other filler or by a solid barrier. The upper run shall be so guarded as to prevent contact therewith either by the worker or by objects carried by him.

In power plants only the lower run of the belt need be guarded.

(e) Overhead chain and link-belt drives, where the chain exceeds two (2) inches in width, are governed by the same rules as overhead horizontal belts and shall be guarded in the same manner as belts.

(f) American or Continuous System rope drives so located that the condition of the rope (particularly the splice) cannot be constantly and conveniently observed, shall be equipped with a "tell-tale" device (preferably electric-bell type) that will give warning when rope begins to fray.

(g) Vertical and inclined belts shall be enclosed by a guard conforming to standards in Part IV, Sections 40 and 42.

(h) All guards for inclined belts shall be arranged in such a manner that a minimum clearance of six (6) feet six (6) inches is maintained between belt and floor at any point outside of guard.

Vertical belts running over a lower pulley more than six (6) feet above floor or platform shall be guarded at the bottom in the same manner as horizontal overhead belts if conditions are such as stated in Rule 220-c, 1 and 3.

A cone-pulley drive with all parts of the lower cone pulley three (3) feet or more above the floor need not be guarded. Where any part of the lower cone pulley is less than three (3) feet from the floor, the pulley and belt shall be guarded in accordance with Part IV, Sections 40 and 42.

Gears, sprockets, and chains are to be guarded in accordance with the following specifications:

(a) A complete enclosure.

(b) A standard guard six (6) feet high extending six (6) inches above the mesh point of the gears.

(c) By a band guard covering the face of gear and having flanges extended inward beyond the root of the teeth on the exposed side or sides. Where any portion of the train of gears guarded by a band guard is less than six (6) feet from the floor a disk guard or a complete enclosure to the height of six (6) feet shall be required.

All sprocket wheels and chains shall be enclosed unless more than seven (7) feet above the floor or platform.

When frequent oiling must be done, openings with hinged or sliding self-closing covers shall be provided.

Friction Drives. Friction drives are treated much like gears:

(a) The driving point of all friction drives when exposed to contact shall be guarded.

(b) All arm or spoke friction drives and all web friction drives with holes in the web shall be entirely enclosed.

(c) All projecting bolts on fraction drives where exposed to contact shall be guarded.

Keys, Set Screws, Etc. The code states that:

All projecting keys, set screws, and other projections in revolving parts shall be removed or made flush or guarded by metal cover. This does not apply to keys or set screws within gear or sprocket casings or other enclosures, nor to keys, set screws or oil cups in hubs of pulleys where they are within the plane of the rim of the pulley.

It is further recommended that no projecting set screws or oil cups be used in any revolving pulley or part of machinery, even though they are within the limits stated in the above paragraph.

Collars and Couplings. Collars and couplings are required to be cylindrical in shape, and screws or bolts used in them must present no hazard.

STARTING AND STOPPING DEVICES

Under this section are treated clutches, cut-off couplings, clutch pulleys, belt shifters, shippers, poles, perches, and fasteners.

Regarding the first of these items, the code provides that:

(a) Clutches, cut-off couplings or clutch pulleys having projecting parts, where such clutches are located seven (7) feet or less above the floor or working platform, shall be enclosed by a stationary guard constructed in accordance with these standards (the "U" type guard is permissible).

NOTE 1: Where clutches, cut-off couplings, or clutch pulleys are so situated within a machine or otherwise guarded by location, the application of this rule is within the discretion of the enforcing authority.

NOTE 2: In engine rooms a guard rail, preferably with toe board, will be permitted instead of the above, provided this room is occupied only by engine-room attendants.

NOTE 3: The use of a bearing support immediately adjacent to a friction clutch or cut-off coupling being recognized engineering practice, only self-lubricating bearings requiring attention at infrequent intervals shall be used in such locations.

An excellent caution in connection with belt and clutch shifters is contained in the following provision:

(c) All belt and clutch shifters of the same type in each shop should move in the same direction to stop machines, i.e., either all *right* or all *left*.

Belt shippers and poles are not recommended, nor are belt perches.

Perhaps no part of the code received greater attention than did belt fasteners, and a considerable number of belting experts, more particularly manufacturers of canvass and rubber belting, were invited to discuss this matter at a special meeting of the Committee. The following provision was finally adopted:

Belts which of necessity must be shifted by hand and belts within six (6) feet of the floor or working platform which are not guarded in accordance with the intent of this code shall not be fastened with metal in any case nor with any other fastening which by construction or wear will constitute an accident hazard.

GUARD STANDARDS

Under this section has been included materials for guard construction, designs of guards, and methods of manufacture.

Expanded metal, perforated or solid sheet metal, and wire mesh on a metal frame have been fixed as the standard materials for guard construction.

(a) Standard conditions will be secured by the use of the following materials: Expanded metal, perforated or solid sheet metal or wire mesh on a frame of angle iron or iron pipe securely fastened to floor or to frame of machine.

(b) All metal should be free from burrs and sharp edges.

(c) Wire mesh should be of the type in which the wires are securely fastened at every cross point either by welding, soldering or galvanizing, except in case of diamond or square wire mesh made of No. 14 gage wire, ¾-in. mesh or heavier.

In the design of guards emphasis is placed on the desirability of making them with hinged sections or removable, where it is necessary to change belts, make adjustments, or oil parts.

Considerable space has been given to details of guard manufacture with information as to sizes of materials, clearances, etc. Illustrations are also used.

The code closes with a few of the more important rules in the care and operation of equipment and a brief discussion of the reasons leading to the adoption of certain features.

ENGINEERING RESEARCH

A Department Conducted by the Research Committee of the A.S.M.E.

Résumé of the Month

A—Research Results

The purpose of this section of Engineering Research is to give the origin of research information which has been completed, to give a résumé of research results with formulas or curves where such may be readily given, and to report results of non-extensive researches which in the opinion of the investigators do not warrant a paper.

Fuels A3-23. How Steam Production Costs were Reduced in a Hand-Fired Return-Tubular Boiler Plant. See *Steam Power A1-23.*

Fuels A4-23. Value of Coke, Anthracite, and Bituminous Coal for Generating Steam in a Low-Pressure Cast-Iron Boiler. A series of steaming tests recently made at the Pittsburgh experiment station of the Bureau of Mines are described in a pamphlet known as Technical Paper No. 303. This paper was prepared by Messrs. John Blizard, James Neil, and F. C. Houghten.

The primary purpose of the tests was to determine the relative steaming values of coke, anthracite, and bituminous coal when burned in a low-pressure boiler, and fired by hand in fairly large quantities at a time.

A secondary purpose of the tests was to separate the heat losses, and to examine them carefully to determine the change in efficiency with the method of firing the fuel and manipulation of the draft dampers, with the rate of evaporation, and with the various fuels burned.

Other purposes may be mentioned, such as determination of the draft used, temperatures and composition of the gases in the flues, furnace, and combustion chamber, and other factors affecting the operation of the boiler.

Before these tests were completed, some special tests were run at the request of the Chamber of Commerce of Pittsburgh, to compare the steaming value and smoke emission of mixtures of coke breeze and Pittsburgh coal with those of the latter alone; results of these tests are also embodied in this report.

Address the Superintendent of Documents, Government Printing Office, Washington, D. C. Price per copy, 10 cents.

Industrial Management A1-23. How Steam Production Costs were Reduced in a Hand-Fired Return-Tubular Boiler Plant. See *Steam Power A1-23.*

Instruments and Apparatus A1-23. Testing of Barometers and Altimeters. This Circular of the Bureau of Standards, No. 46, describes the testing of mercurial and aneroid barometers at the Bureau and announces the fees which are charged for the various tests.

Address the Superintendent of Documents, Government Printing Office, Washington, D. C. Price per copy, 10 cents.

Machine Tools A1-23. Lathe Breakdown Tests of Some High-Speed Tool Steels. This report known as Technologic Paper No. 228 was prepared by H. J. French of the Bureau of Standards and Jerome Strauss of the U. S. Naval Gun Factory. In it, comparative lathe cutting tests are reported for about 25 brands, representing various compositions.

Important conclusions drawn from the described tests may be summarized as follows:

1 Breakdown tests, in which endurance of tools is determined under definite working conditions, are not satisfactory as the basis of purchase for high-speed tool steels.

2 In certain severe breakdown tests with roughing tools on 3 per cent nickel-steel forgings, in which high frictional temperatures were produced, it was found that the performance of commercial low-tungsten-high-vanadium and cobalt steels was superior to that of the high-tungsten-low-vanadium type and special steels containing about 1/4 per cent uranium or 3/4 per cent molybdenum. The average power consumption in all cases was practically the same.

3 Modification in test conditions, including small changes in tool angles but principally changes in cutting speed, more markedly affected the performance of steels containing cobalt or special elements, such as uranium or molybdenum, than that of the basic types (plain chromium-tungsten-vanadium steels).

4 The relatively poor endurance of the high-tungsten steels under severe working conditions was not observed in more moderate tests, made on the same test log with equal cutting speed and depth of cut but with reduced feed, in which the frictional temperatures produced were not so high. Also in these latter tests the performance of the cobalt steels was better than either the low- or high-tungsten steels.

5 Hardness determinations and examination of fractures indicate that the various types of commercial high-speed steel show differences in behavior under heat treatment and in physical properties which probably are of importance under moderate working conditions and might counterbalance slight advantages in performance.

The paper contains fifteen tables. Address the Superintendent of Documents, Government Printing Office, Washington, D. C.

Non-Ferrous Metals A4-23. Solders for Aluminum. Most of the metals commonly used in solders, except magnesium, are electropositive to aluminum, so that any metals used in making a soldered joint of aluminum act electrolytically in the presence of moisture, accelerating the corrosion of the aluminum. Magnesium cannot be utilized because it disintegrates rapidly in the presence of moisture. Soldered joints of aluminum exposed to moisture should be protected by paint or varnish. Various compositions of zinc-tin and zinc-tin-aluminum solders give the best results. The tensile strength of a good aluminum solder is about 7000 lb. per sq. in. Those with higher tensile strength usually have such a high temperature of complete liquidation that they are unsuited for soldering purposes.

Circular No. 78 of the Bureau of Standards entitled, Solders for Aluminum, has recently been revised. It will soon be available from the Superintendent of Documents, Government Printing Office, Washington, D. C., at 5 cents a copy.

Steam Power A1-23. How Steam Production Costs were Reduced in a Hand-Fired Return-Tubular Boiler Plant. During the course of an investigation conducted by the fuel section of the Bureau of Mines, on a hand-fired return-tubular boiler plant, it was found that the average cost of fuel to produce 1000 lb. of steam was $0.5287. Tests conducted after some simple changes had been made in the furnaces, and in the control of the boilers, showed the previous high cost of fuel per 1000 lb. of steam could be reduced to the reasonable figure of $0.3540, or the equivalent of over 30 per cent saving in fuel cost.

These tests were made by A. R. Mumford, assistant fuel engineer of the Bureau of Mines, and consisted of a comparative study in the use of pea-size anthracite and bituminous coal without smoke. They involved experimental modifications of the setting, modifications in the method of control of the boilers, and improvement in the methods of firing. This last resolved itself into a comparative time study.

The total savings shown possible by the modifications introduced are approximately 900 tons of coal in an eleven-month period, and approximately $12,500 in total fuel cost. Reports of Investigations, Serial No. 2455, U. S. Bureau of Mines, Washington, D. C.

Steel, Its Treatment and Products A1-23. Lathe Breakdown Tests of Some High-Speed Tool Steels. See *Machine Tools A1-23.*

B—Research in Progress

The purpose of this section of Engineering Research is to bring together those who are working on the same problem for cooperation or conference, to prevent unnecessary duplication of work, and to inform the profession of the investigators who are engaged upon research problems. The addresses of these investigators are given for the purpose of correspondence.

Instruments and Apparatus B2-23. Saybolt Universal Viscosimeter. A conference was held at the Bureau of Standards, November 14 with members of the American Petroleum Institute, as a result of which a committee of 5 members of the Institute was appointed to cooperate with the Bureau in expediting the more accurate standardization of the Saybolt universal viscosimeter.

The Institute and the Bureau are also cooperating with the Society of Automotive Engineers and the Interdepartmental Committee on Petroleum Products in the development of a numbering system for lubricating oils based on their viscosity.

Iron and Steel B1-23. Wear Tests of Steel. An investigation of the resistance to wear of steels has been in process at the Bureau of Standards for some time. During the past month a study has been made of the effect of keeping the surfaces of the specimens clean and free from all adhering abraded particles. A cloth buffing wheel, rotated at high speed by electric motor, has been used successfully for this purpose. It has been found that when the wearing surfaces are thus kept free of abraded metallic dust, the rate of wear drops to an almost negligible quantity compared with the rate when the wearing surfaces are not kept clean by the buffing wheel. Address Dr. Geo. K. Burgess, Director of the Bureau of Standards, Washington, D. C.

Lubricants B1-23. Saybolt Universal Viscosimeter. See *Instruments and Apparatus B2-23.*

Non-Ferrous Metals B2-23. Gases in Monel Metal. The Bureau of Standards has just completed determinations of oxygen and hydrogen in samples representing three phases of the deoxidation of monel metal. The samples were all from 50-lb. blocks cast during the progress of a regular heat. These samples represent (1) the metal at the time of tapping the furnace before the addition of any deoxidizers; (2) the above metal after the addition of ferro manganese in the ladel, and (3) the above metal after the further addition of magnesium in the ladle, that is, after all additions have been made. Both oxygen and hydrogen in the metal decreased rapidly with the progress of deoxidation. The finished metal, as represented by the last sample of this heat and

by samples of completely deoxidized metal from two other heats, contains from 0.002 to 0.005 per cent oxygen. All samples appear rather porous under a magnification of 100.

A sample of monel metal prepared as above, except that a portion of the deoxidation was carried out in the furnace rather than entirely in the ladle, showed no porosity, and no oxygen could be detected. A sample of monel metal from a Herault furnace heat, which had been completely deoxidized in the furnace, likewise was entirely sound and contained no oxygen. Of the five samples of finished monel metal examined the three which were deoxidized by addition of ferromanganese and magnesium in the ladle were porous and contained from 0.002 to 0.005 per cent oxygen, while the two which were deoxidized entirely or in part in the furnace were sound and contained no oxygen.

Paper B1-23. THE TENSILE STRENGTH OF PAPER. There are a number of devices for determining the tensile or breaking strength of paper, but the procedure in carrying out the tests has not been standardized; thus all sorts of combinations of width and length of the test specimen, rate of applying the load, and time during which the specimen is under stress, are in use.

A study of these various factors recently completed by the Bureau of Standards indicates that there is considerable difference in the amount of stretch when the factors are varied, but when only the strength is to be considered, the length of the specimen, within limits, is of negligible importance, while the strength is almost proportional to the width.

Paper B2-23. THE MULLEN TESTER FOR MEASURING THE QUALITY OF PAPER. What is known as the Mullen tester is used almost universally in this country for determining the bursting strength of paper, and on this factor is based to a large extent the measure of the quality of the paper. It often happens, however, that a sheet may be so made or so sized as to have a very high bursting strength and yet show up very poorly in a tearing or folding test.

The Bureau of Standards is working on a supplementary test employing two steel rollers which produce a crease in the paper under controlled conditions of pressure and time. The bursting strength is determined before and after such folding. The loss of strength under these conditions is an excellent indication of the brittleness of the paper. The method, however, must still be standardized. A report on this subject will be published in the near future.

Rope B1-23. TESTS FOR NEW DESIGN OF LARGE HAWSERS. Tensile tests were made during the past month at the Bureau of Standards on twenty-one samples of very large hawsers. The purpose of these tests was to determine the comparative strength of a new type of construction for manila rope as compared with the standard method of construction. In the new type the inner yarns of the strands are untwisted. The strands are made up of several outer layers of twisted yarns binding this inner compact mass of fibers; these strands being twisted in the usual manner to form the rope. The tests showed that in all cases the new type of construction increases the strength of the rope.

Steel, Its Treatment and Products B1-23. CARBURIZATION OF STEEL. An investigation of the effect of the quality of steel upon its carburizing properties, and particularly its hardening properties after carburization, was suggested to the Bureau of Standards by metallurgists as a problem of very considerable commercial importance. As soon as the necessary material (abnormal steels) can be obtained, the work will be started.

F—BIBLIOGRAPHIES

The purpose of this section of Engineering Research is to inform the profession of bibliographies which have been prepared. In general this work is done at the expense of the Society. Extensive bibliographies require the approval of the Research Committee. All bibliographies are loaned for a period of one month only. Additional copies are available, however, for periods of two weeks to members of the A.S.M.E. These bibliographies are on file at the headquarters of the Society.

Heat Transmission F1-23. HEAT EXCHANGERS. A bibliography consisting of two pages. Search No. 3717. Address the A.S.M.E., 29 West 39th Street, N. Y. C.

Machine Design F1-23. RING-OILING SYSTEMS. A bibliography consisting of one page. Search No. S 3683. Address the A.S.M.E., 29 West 39th Street, N. Y. C.

CORRESPONDENCE

CONTRIBUTIONS to the Correspondence Department of MECHANICAL ENGINEERING are solicited. Contributions particularly welcomed are discussions of papers published in this journal, brief articles of current interest to mechanical engineers, or comments from members of The American Society of Mechanical Engineers on activities and policies of the Society in Research and Standardization.

Methods of Calculating the Diameters of Open-Belt Speed Cones

TO THE EDITOR:

The following is submitted as a rational method for calculating the radii of open-belt speed cones.

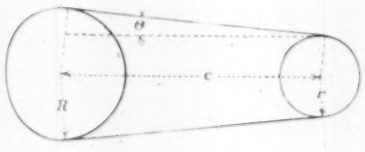

FIG. 1 DIAGRAM OF OPEN-BELT DRIVE

Let L = length of belt
c = distance between pulley centers
r = radius of smaller pulley
k = velocity ratio, whence
$R = kr$ = radius of larger pulley.

Then, referring to Fig. 1,

$$L = 2c\cos\theta + r(\pi - 2\theta) + kr(\pi + 2\theta)$$

$$= 2c\,\frac{\sqrt{c^2 - r^2(k-1)^2}}{c} + \pi r(k+1) + r(k-1)2\theta$$

$$= 2c\sqrt{1 - \left[\frac{r(k-1)}{c}\right]^2} + 2c\left(\frac{\pi}{2}\ \frac{k+1}{k-1}\right)\frac{r(k-1)}{c}$$

$$+ 2c\,\frac{r(k-1)}{c}\sin^{-1}\frac{r(k-1)}{c}$$

Let $\dfrac{r(k-1)}{c} = u$; then, substituting in the preceding equation,

$$\frac{L}{2c} = \left[1 + (-u^2)\right]^{\frac{1}{2}} + \left(\frac{\pi}{2}\ \frac{k+1}{k-1}\right)u + u\sin^{-1}u$$

$$= 1 + \frac{1}{2}(-u^2) + \frac{\frac{1}{2}\left(-\frac{1}{2}\right)(-u^2)^2}{\lfloor 2}$$

$$+ \frac{\frac{1}{2}\left(-\frac{1}{2}\right)\left(-\frac{3}{2}\right)(-u^2)^3}{\lfloor 3}$$

$$+ \frac{\frac{1}{2}\left(-\frac{1}{2}\right)\left(-\frac{3}{2}\right)\left(-\frac{5}{2}\right)(-u^2)^4}{\lfloor 4} + \cdots$$

$$+ \left(\frac{\pi}{2}\ \frac{k+1}{k-1}\right)u$$

$$+ u\left[u + \frac{u^3}{2\cdot 3} + \frac{3u^5}{2\cdot 4\cdot 5} + \frac{3.5u^7}{2\cdot 4\cdot 6\cdot 7} + \frac{3.5.7u^9}{2\cdot 4\cdot 6\cdot 8\cdot 9} + \cdots\right]$$

or

$$\frac{L}{2c} - 1 = \left(\frac{\pi}{2}\ \frac{k+1}{k-1}\right)u + \frac{1}{2}u^2$$

$$+ \frac{1}{24}u^4 + \frac{1}{80}u^6 + \frac{5}{896}u^8 + \frac{7}{2304}u^{10} + \cdots$$

Let $\dfrac{L}{2c} - 1 = V$ and

$$u = AV + BV^2 + CV^3 + DV^4 + EV^5 + FV^6 + \cdots.$$

Substituting the series in u for V in the series in V gives

$$u = A\left(\frac{\pi}{2}\frac{k+1}{k-1}\right)u + A\frac{1}{2}u^2 + A\frac{1}{24}u^3 + + A\frac{1}{80}u^5 + \cdots$$
$$+ B\left(\frac{\pi}{2}\frac{k+1}{k-1}\right)u^2 + B\left(\frac{\pi}{2}\frac{k+1}{k-1}\right)u^3 + B\frac{1}{4}u^4$$
$$+ B\frac{1}{24}\left(\frac{\pi}{2}\frac{k+1}{k-1}\right)u^5 + \cdots$$
$$+ C\left(\frac{\pi}{2}\frac{k+1}{k-1}\right)^2 u^3 + C\frac{3}{2}\left(\frac{\pi}{2}\frac{k+1}{k-1}\right)^2 u^4$$
$$+ C\frac{3}{4}\left(\frac{\pi}{2}\frac{k+1}{k-1}\right)u^5 + \cdots$$
$$+ D\left(\frac{\pi}{2}\frac{k+1}{k-1}\right)^4 u^4 + D\frac{3}{2}\left(\frac{\pi}{2}\frac{k+1}{k-1}\right)^3 u^5 + \cdots$$
$$+ E\left(\frac{\pi}{2}\frac{k+1}{k-1}\right)^5 u^5 + \cdots$$

Equating like coefficients,

$$A = \left(\frac{2}{\pi}\frac{k-1}{k+1}\right) \quad B = -\frac{1}{2}\left(\frac{2}{\pi}\frac{k-1}{k+1}\right)^3$$
$$C = \frac{1}{2}\left(\frac{2}{\pi}\frac{k-1}{k+1}\right)^3$$
$$D = \left[\frac{1}{24}\left(\frac{2}{\pi}\frac{k-1}{k+1}\right)^5 + \frac{5}{8}\left(\frac{2}{\pi}\frac{k-1}{k+1}\right)^7\right]$$
$$E = \frac{1}{48}\left(\frac{2}{\pi}\frac{k-1}{k+1}\right)^9 - \frac{3}{8}\left(\frac{2}{\pi}\frac{k-1}{k+1}\right)^{11} + \frac{3}{48}\left(\frac{2}{\pi}\frac{k-1}{k+1}\right)^{13} + \frac{15}{16}\left(\frac{2}{\pi}\frac{k-1}{k+1}\right)^{15}$$
$$F = -\left[\frac{1}{80}\left(\frac{2}{\pi}\frac{k-1}{k+1}\right)^7 - \frac{1}{48}\left(\frac{2}{\pi}\frac{k-1}{k+1}\right)^9 + \frac{1}{16}\left(\frac{2}{\pi}\frac{k-1}{k+1}\right)^{11} + \frac{5}{96}\left(\frac{2}{\pi}\frac{k-1}{k+1}\right)^{15} - \frac{15}{16}\left(\frac{2}{\pi}\frac{k-1}{k+1}\right)^{17} + \frac{15}{96}\left(\frac{2}{\pi}\frac{k-1}{k+1}\right)^{19} + \frac{75}{32}\left(\frac{2}{\pi}\frac{k-1}{k+1}\right)^{21}\right]$$

Substituting these values in

$$u = AV + BV^2 + CV^3 + DV^4 + EV^5 + FV^6 + \cdots$$

where $u = \frac{r(k-1)}{c}$ and $V = \frac{L}{2c} - 1$, and letting $\frac{2}{\pi}\frac{k-1}{k+1} = w$,

$$r = \frac{c}{k-1}\left[wV - \frac{1}{2}w^3V^2 + \frac{1}{2}w^5V^3 - \left(\frac{1}{24}w^5 - \frac{5}{8}w^7\right)V^4 + \left(\frac{1}{48}w^7 - \frac{3}{8}w^{11} + \frac{3}{48}w^{13} + \frac{15}{16}w^{15}\right)V^5 - \left(\frac{1}{80}w^7 - \frac{1}{48}w^9 + \frac{1}{16}w^{11} + \frac{5}{96}w^{15} - \frac{15}{16}w^{17} + \frac{15}{96}w^{19} + \frac{75}{32}w^{21}\right)V^6 + \cdots\right]$$

If $k = 1$, this equation reduces to

$$r = \frac{1}{\pi}\left(\frac{L}{2} - c\right)$$

The values of r given by this series may be calculated to any desired degree of accuracy by taking a large enough number of terms.

For values of angle θ up to four or five degrees the series converges very rapidly; the rapidity of convergence falling off, however, as the belt angle is increased.

The first two or three terms will generally be sufficient for cases with small belt angles; while the fourth should suffice for angles up to and including 10 or 11 deg. for θ.

In using this formula either the belt length should be calculated to fit a pair of pulleys at the start or some convenient belt length should be fixed upon and then the pulleys calculated to fit the belt.

The dimensions L, c, and r must, of course, always be taken in the same units.

W. H. Wise.

Missoula, Mont.

To the Editor:

In a correctly designed speed-cone drive the same belt will work in all positions with equal tightness. This is accomplished by so arranging the sum of the diameters that the length of belt required to pass over each pair of steps will remain constant. By comparing the formula for the exact length of a crossed belt [1] with that for the exact length of an open belt [2], it will be seen that in the former case the length is a function of the center distance and the sum of the diameters, while in the latter the length is a function of the center distance and the sum and difference of the diameters.

$$L = \frac{1}{2}(D + d)\left[\pi + 2\sin^{-1}\frac{D+d}{2c} + 2\cot\left(\sin^{-1}\frac{D+d}{2c}\right)\right] \quad [1]$$

$$L = \frac{\pi}{2}(D + d) + (D - d)\sin^{-1}\frac{D-d}{2c} + 2C\cos\left(\sin^{-1}\frac{D-d}{2c}\right) \quad [2]$$

where

D = diameter of the larger pulley
d = diameter of the smaller pulley
c = center distance between shafts, and
L = length of belt.

Therefore, if the belt is to work with equal tightness when crossed, since the center distance is constant it is sufficient to so design the steps that the sum of the diameters of one pair shall equal the sum of the diameters of any other pair. In other words,

$$D_1 + d_1 = D_2 + d_2 = D_3 + d_3, \text{ etc.}$$

In the case of an open belt, however, not only the sum but also the difference of the diameters must be constant; this condition it is impossible to satisfy, hence there can be no direct solution.

Several excellent graphical methods have been devised. In practice, however, it is difficult to make a layout sufficiently accurate; very often the center distance is too long for the equipment on hand, so that a layout must be made to a small scale, and a very slight error will greatly affect the final results. None of the theoretical formulas known can be considered a convenient way of solving the problems because of their complexity and length.

The following is the method used by the writer in constructing a logarithmic chart which greatly simplifies the calculations of cone-pulley diameters. The formula for the length of an open belt is given by Professor Unwin as follows:

$$L = \frac{\pi}{2}(D + d) + 2c\left[1 + \frac{(D-d)^2}{8c^2}\right] \quad [3]$$

which is very nearly the exact length. Let D_0 and d_0 be the diameters of one pair and D_1 and d_1 the diameters of any other pair of steps in the same cone; then, the length of the belt being the same,

$$L = \frac{\pi}{2}(D_0 + d_0) + 2c\left[1 + \frac{(D_0 - d_0)^2}{8c^2}\right]$$
$$= \frac{\pi}{2}(D_1 + d_1) + 2c\left[1 + \frac{(D_1 + d_1)^2}{8c^2}\right] \quad [4]$$

Solving for $D_1 + d_1$,

$$D_1 + d_1 = D_0 + d_0 + \frac{(D_0 - d_0)^2 - (D_1 - d_1)^2}{2\pi c} \quad [5]$$

If D_0 and d_0 be the diameters of a pair selected to give the speed ratio $k = 1$, then $D_0 = d_0$ and $(D_0 - d_0) = 0$. Substituting this value in [5],

$$D_1 + d_1 = D_0 + d_0 - \frac{(D_1 - d_1)^2}{2\pi c} \quad [6]$$

which means that for open-belt service the sum of the diameters of any pair of pulleys equals the sum of the diameters of a pair of mutually equal pulleys for the ratio $k = 1$ minus a correction (K) whose value is

$$K = \frac{(D_1 - d_1)^2}{2\pi c} \quad [7]$$

Since the value $(D_1 - d_1)$ is unknown until $(D_1 + d_1)$ is found, an approximation must be used, which may be assumed as

$$D_1 - d_1 = (D_1 + d_1)\frac{k - 1}{k + 1} \quad [8]$$

The value of the sum of the diameters $(D_1 + d_1)$ can now be found by solving [6]. In most cases the results thus obtained are sufficiently accurate for practical purposes. However, when the speed ratio k is large and the center distance very short, it is advisable to solve [6] a second time, substituting a closer approximation of $D_1 - d_1$, namely,

$$(D_1 + d_1)\frac{k - 1}{k + 1}$$

where $(D_1 + d_1)$ has the value as found in the first trial. This result is accurate enough for any condition met in practice.

The chart was evolved with the idea of eliminating as much as possible of the labor attached to calculating the correction number from Formulas [7] and [8]. For convenience in constructing the chart the expression for the correction number K can be written

$$K = \frac{(D_1 + d_1)^2}{2\pi \left(\frac{1}{\left(\frac{k - 1}{k + 1}\right)}\right) c}$$

The chart (Fig. 2) consists of four scales; the values on the scale representing the logarithm of the center distance c must be added to the value on the scale marked "Speed Ratio," which equals the logarithm of $1 \div [(k - 1) \div (k + 1)]^2$, and the resulting logarithm should be subtracted from $\log (D + d)^2 \div 2c$ on the scale marked "Sum Diameters." The remainder is the logarithm of the correction number and can be read on the fourth scale representing the correction number.

The procedure of calculating the correct diameters of any pair of steps for open-belt service can be best illustrated by an example.

Given the diameters of a pair of even steps for ratio $k = 1$, each equal to 9 in.; center distance = 30 in.; speed of one shaft = 500 r.p.m.; speed of the other shaft = 100 r.p.m.

1 Add the diameters of the given even pair:

$$9 \text{ in.} + 9 \text{ in.} = 18 \text{ in.}$$

2 Express the speed ratio as follows:

$$k = \frac{\text{higher speed}}{\text{lower speed}} = \frac{500}{100} = 5$$

3 Set one point of a pair of dividers at 30 on the scale of Fig. 2 representing the center distance and the other point at 5 on the scale marked "Speed Ratio."

4 Keeping the above setting, place one point of the dividers at 18 on the scale marked "Sum Diameters;" the other point of the dividers will then indicate the first approximation of the correction number on the scale marked "Correction Number." In this example the first approximation equals 0.760.

5 Subtract this correction number from the sum of the diameters of the two even pulleys:

$$18 - 0.760 = 17.240$$

6 Keeping the same setting of the dividers as in (3), place one point at 17.240 on scale marked "Sum Diameters;" the other point will stop at 0.695, which is the second and closer approximation of the correction number.

7 Subtract this correction number (0.695) from the sum of the diameters of the even pair, then

$$S_K = 18 - 0.695 = 17.305$$

in which S_K is the corrected sum of diameters for the ratio $k = 5$.

8 The last step is to find the diameter of each pulley separately.

$$\text{Diameter of smaller pulley} = \frac{S_K}{k + 1}$$

$$\text{Diameter of larger pulley} = S_K - d$$

Then in the present example

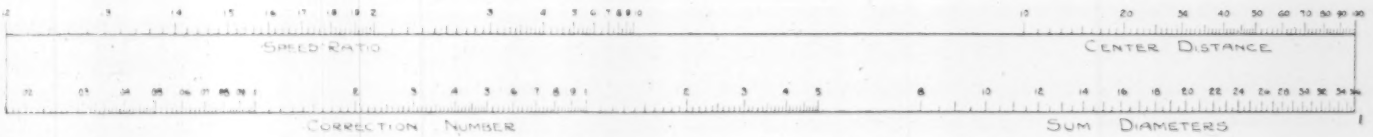

FIG. 2 CORRECTION CHART FOR USE IN CALCULATING CONE-PULLEY DIAMETERS

$$d = \frac{17.305}{6} = 2.884 \text{ in.}$$

$$D = 17.305 - 2.884 = 14.421 \text{ in.}$$

If the correction number is carefully read from the chart the final results will not vary on the average more than 0.005 in. from the most accurate mathematical calculations, and the whole procedure should not take over three minutes.

TABLE 1 CALCULATIONS OF THREE DIFFERENT CONE DRIVES

No.	c	k	$D_0 + d_0$	K from chart	S_K	D_1	d_1	L
1	4.40	1	32	1.340	30.660	24.528	6.132	130.266
	4.40	4						130.285
2	4.60	1	20	0.256	19.744	14.808	4.936	151.416
	4.60	5						151.417
3	4.30	1	18	0.695	17.305	14.421	2.884	88.274
	4.30	5						88.295

For the purpose of checking the accuracy of the chart, the diameters and the lengths of belts of three different cone drives have been computed, the results being given in Table 1.

DAVID TURCOTT.

Beloit, Wis.

With Reference to the Discussion on High-Temperature and High-Pressure Steam Lines

TO THE EDITOR:

It has been called to my attention that as presented on page 294 of the May issue of MECHANICAL ENGINEERING, the second paragraph of my closure to the discussion of my paper on High-Pressure and High-Temperature Steam Lines may be interpreted as an unfair criticism of Mr. Barrett, one of the discussors. Undoubtedly Mr. Barrett's discussion was prepared carefully and there was no desire on my part to pass on his engineering ability for which I have every respect. I desire to correct any different impression that may be derived from my closure.

B. N. BRODIO.

New York, N. Y.

MECHANICAL ENGINEERING

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Immigration Policy Places New Responsibilities on the Engineer

H. V. COES

FROM all sides we constantly hear of labor shortage. The deflation period in 1921 seemed to indicate a large surplus of labor. As soon, however, as business began to revive, as it did the past year, the temporary surplus was immediately absorbed, and now one important industrial executive estimates the labor shortage in the United States at the present time at 600,000. The people of the United States have made up their minds that they are going to control the character of the raw material that is to make up their citizenship and their neighbors, and the present policy is to restrict immigration from those countries whose people are not readily assimilated. The shortage threatens to become permanent.

A study of our principal industries such as textiles or steel shows a continuous shift in the various nationalities engaged therein over a long period of years. The probable reason for it is that the second or third generation of a given group of immigrants will not do the work their grandparents did—they have advanced to a higher scale of living and the unskilled worker is recruited from a new group of immigrants. This substitution of labor, both male and female, has run through the nations of Western Europe and, in the last decade or two, has largely focused on those of Eastern Europe. How much farther it can go in the white race it is hard to say. It has reached a point in certain places where there has been considerable agitation for coolie labor. I doubt very much whether the United States will ever admit labor of that class.

It has been the policy of the United States for over seventy years to depend upon immigration to furnish the necessary unskilled labor for our industries. Last year the number of immigrants admitted to this country was approximately 360,000; pending legislation would limit the eligibles to 170,000. The vital question, then, is, can the country expand and prosper with such a limited supply of new labor? A glance at the following statistics may be of interest.

Year	Number of Immigrants	
1820	8,400	
1830	23,000	
1840	80,000	Period of industrial expansion
1854	420,000	
1862	72,000	
1905	1,026,000	

In other words, when the United States was an agricultural country we did not need large immigration. As our industries developed, however, our immigration rose very rapidly. It fell to a low point on account of the Civil War, but throughout that period we received a total of about 620,000. In the past century the United States has received 35,000,000 immigrants. They have not all remained here, however. For instance, from 1909 to 1923, 5,500,000 departed, while our gain in immigration during that same period was 5,125,000.

The question is asked, What interest has the engineer in a restricted immigration policy? The answer is that the engineer, appreciating his important function in developing and sustaining civilization, must provide workers of metal and wood to fill the ranks that have normally been recruited from immigrants. Opportunity awaits the grasping. Capital will be required, but will undoubtedly be forthcoming to furnish backing for the design and manufacture of machines and devices that are commercially practical for lessening the hand work of the world. The increasing material needs of the inhabitant of a modern civilized country means that industry must increase. The new personnel for an increased industry will not come from restricted immigration even though quotas be made net, taking into account emigration and immigration. New and better machines under the guidance of modern management methods form an important part of the solution of the problem of labor shortage. Providing the machines and the management methods is largely an engineering responsibility. In other words, the engineer and management must devise ways and means to release common labor from some of its present assignments and graduate it into the ranks of semi-skilled and skilled labor, substituting therefor mechanical appliances to do the work previously done by common labor. This substitution need not, in fact should not, be confined to the activities now performed by common labor, but similar substitution must be made all along the industrial path if we are to maintain our industrial supremacy.

H. V. COES[1]

Coast to Coast by Air

THE flight of Lieutenants John A. Macready and Oakley G. Kelly from Long Island to San Diego is primarily of interest as showing the progressive spirit governing the Army Air Service.

It is certainly no accident that at the time of this writing several world records are held by the Department, among others such important ones as the speed record, the endurance record, and now the non-stop distance flight. (The fact that for technical reasons this particular record cannot be homologated by the International Aeronautical Association, does not, of course, in any way affect its authenticity or value.) The coast-to-coast flight was a severe test not only of the plane and engine, but also of the training and personal ability of the men. Moreover it is not an isolated performance, a stunt. The same men have flown for other long distances, though not as great, of course, as that covered in the present flight. Other flights such as the one from Long Island to Alaska and particularly the recent flight to Porto Rico have shown that the Army Air Service is capable of what would have appeared to be only a few years ago unbelievable performances.

The machine used was a T-2 monoplane designed by Anthony G. H. Fokker and built by the Netherlands Aircraft Corporation to take the Liberty motor. The structural weight empty is 5100 lb. and the useful load for commercial operation is 3500 lb. The total wing area is 940 sq. ft. The maximum speed fully loaded is 105 miles per hour, and the ceiling approximately 11,000 ft.

In order to adapt the machine for the coast-to-coast flight certain changes were made. By the use of an extra tank in the cabin and an extra gravity tank in the wing, the total gasoline capacity was increased to some 735 gal. and the oil capacity to 30 gal. The total

[1] Chairman, Materials Handling Division, A.S.M.E.

weight fully loaded was thus increased to over 10,000 lb. An oil radiator was provided. Anti-leak compound with an appropriate pressure pump was carried for use in the radiator or water jackets in case of leak. A special tank was provided to catch overflow from the radiator or its expansion tank, so that the loss of water on a long trip was minimized. Spare batteries were taken along, as well as a spare glass tube for the gasoline level gage among other items. A second set of flying and engine controls were installed in the cabin, with a communicating door between the pilot and the cabin so as to facilitate interchange between the two men. A sliding door was provided near the pilot in order to enable him to thrust his body right outside the plane.

The power plant was a Liberty engine, and it is stated that, with the exception of a short period at the beginning of the trip, it operated at about 90 per cent of its full power throughout the flight.

The present flight, as well as the flight from England to Australia by the Smith brothers in their Vimy biplane, has shown that highly experienced fliers can find their way even under adverse conditions by compass and dead reckoning. It has also shown, however, that it takes a highly experienced flier to do so, and that lack of ground markings is a serious obstacle to long-distance flight.

It may be a long time before flying from New York to San Francisco will become an every-day occurrence and a means of saving time for the ordinary busy man. Lady Carnarvon's attempt to reach her dying husband by air from England to Egypt, it may be said, failed mainly because of the extreme discomfort of long flight to those not accustomed to that mode of travel.

From a military point of view, however, the importance of the achievement of Macready and Kelly is very clear, and it is also of unquestioned significance as showing that while the number of planes available to the War Department is pitifully small for such a great country as ours, the men in the Department are capable of performing wonders even with what equipment they have.

Store Winter Coal Now!

ALL INDUSTRIES and individuals are asked to store a winter's supply of fuel during the summer months. The Coal Commission has pointed out that the storage of coal in this manner will even the demand for coal throughout the year, thereby rendering its production more economical and equalizing the demand for transportation. Secretary Hoover, in a letter to the Society, points out that the producing capacity and consuming demands of the country have advanced beyond our transportation facilities, and stresses the importance of both consuming and producing industries cooperating with the railroad managements to secure the most efficient operation of their lines. The transportation peak of the country occurs during October. It is extremely important, therefore, that coal be purchased and stored within the next three months so that the burden of moving this fuel will not be added to the difficult transportation period of the fall.

The importance of storing coal applies not only to the railroads, the public utilities, and the industries, but also to domestic users. The Storrs Plan of domestic coal storage was outlined in the May issue of MECHANICAL ENGINEERING.

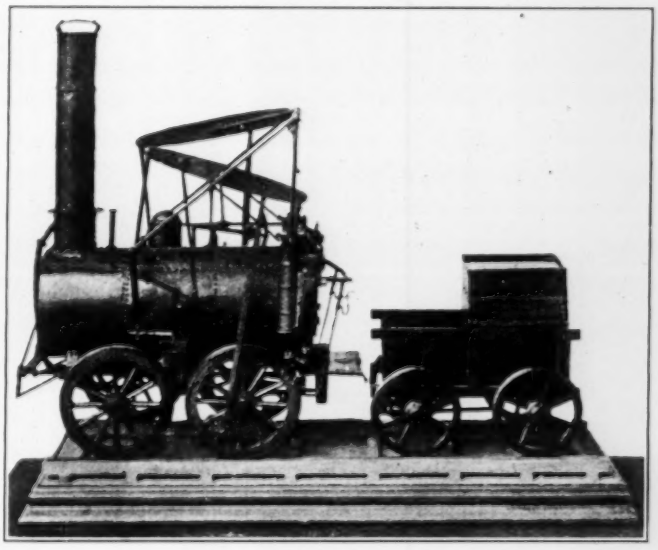
The American Engineering Council has appointed a committee to make a coal-storage survey and issue an authoritative statement covering the engineering, chemical, and economic factors involved in the storage of coal, and how they may be employed to relieve the present complex coal situation. It is hoped that this committee will report early in November, 1923.

The problem of coal storage is far-reaching and fundamental. It places a responsibility on each member of the Society to discuss the subject in his business and social contacts and arouse general public attention. The organized groups of the Society are mobilizing for duty. The Fuels Division is assisting the committee of the American Engineering Council, and in addition will hold a session at the A.S.M.E. Annual Meeting in December with papers on the storage of fuel. The Materials Handling Division is cooperating in the arrangements for this session. Each Local Section will be called upon by the American Engineering Council committee to assist in the survey.

Store winter coal now!

One Hundred Years of Transportation

THE centennial celebration of the Delaware and Hudson Company has served to recall the efforts of pioneers in creating a market for the "stone coal," as anthracite was then called, which was discovered near Carbondale, Pa., in 1799. There was doubt as to the ability of "stone coal" to burn on a grate. However, the war of 1812 cut off the normal supply of charcoal and the use of anthracite as a substitute was pushed. About this time William Wurts obtained a large acreage of coal lands near Carbondale and, with his brother Maurice, opened mines and attempted to market the product in Philadelphia. They were compelled to abandon this project to their competitors who were more advantageously located, and turned to New York for the outlet. So the Delaware and Hudson Company was organized to construct a canal connecting the waters of the Delaware and Hudson Rivers. A portion of



THE "STOURBRIDGE LION," THE FIRST STEAM LOCOMOTIVE RUN ON RAILS IN AMERICA

the route from mine to market was over a range of mountains and a gravity railroad was built using inclined planes and stationary hoisting engines.

In 1829 four locomotives were imported from England for use on the gravity railroad. The *America*, built by George Stephenson, arrived on January 15, 1829, and the other three, built by Foster Rostrick, came in May. On August 8 one of the three, the *Stourbridge Lion*, was operated on a section of the track. The test convinced the engineers that the track would not stand the weight of the *Lion* or the side thrust of the wheels on curves. Rebuilding the road to withstand the stresses was considered but for various reasons was found to be impracticable, and the use of locomotives abandoned. The *Stourbridge Lion* was the first locomotive placed on any track outside of England and the first that ever turned a wheel on the Western Hemisphere. It was imported solely to transport and market anthracite.

In a country depending so completely on transportation as does the United States, the centennial of a pioneer transportation company is of great interest. Certainly we can have no accurate conception today of the courage of the pioneers who overcame the prejudices against anthracite and who conquered the physical difficulties of bringing the coal to market.

Transportation conditions a century ago were in at least one respect similar to those of the present day. Locomotives had been known for twenty-five years before the importation of the four engines by the Delaware and Hudson Company. The locomotive did not come into general use, however, until the demands for its services could be met commercially. Today the airplane, largely a war development, is waiting for commercial needs to require its unique transportation ability and to compel the expenditure of money for the research and development that will perfect it for commercial use.

Engineering in India

ENGINEERING projects of great magnitude are under way and under consideration in India, according to a report recently submitted to the Department of Commerce by Trade Commissioner Batchelder. It is estimated that nearly a million dollars is needed to carry out all the plans, among which are the following:

The Madras Presidency proposes to expend about $45,000,000 within the next five years, for irrigation, roads, and other public works. Bombay plans to spend $61,000,000 on irrigation alone, besides continuing the port-development works and the new schoolhouses required to carry out the terms of the new compulsory education act. The United Provinces need $30,000,000 within the same period for irrigation, forests, and other public works, while the Punjab has extensive plans for irrigation and hydro-electric plants requiring $140,000,000 before 1940.

Bengal has decided to build a $10,000,000 bridge across the Hoogly in Calcutta, and there will be further expenditures on the improvements of the port and for ameliorating the housing and congested traffic problems. The total desired for all these government and municipal public works cannot be less than $300,000,000. Besides, it is intended to spend about $500,000,000 in the next five years for new construction, repairs, and additional rolling stock on the government railways.

Some interesting communications concerning engineering in India have come during recent months from J. D. Rogers, representative of The Baldwin Locomotive Works at Calcutta. Mr. Rogers has spent some time in Africa—nearly three years in South Africa and later traveling in Portuguese East Africa and neighboring sections. His message to every American who has gone or expects to go into the foreign field of engineering is to remember that he represents not only some particular interest but the whole American engineering profession. Extracts from Mr. Rogers' letters follow:

India offers great opportunity for capital to be employed in development such as manufacturing, extension of irrigation, and making the great river system navigable. With proper expenditures of money the terror of the monsoons can be eliminated. There will be no suffering from either drought or flood. The Bengal government is to spend $2,000,000 on a canal at Calcutta. The engineer in charge tells me that all of his estimates are based on using American equipment, as we have solved the question of eliminating labor.

I have made a complete circuit of India; this means covering an area equivalent to about two-thirds of that of the United States. Travel here is very comfortable as the railway equipment is well adapted to the conditions. There are about 15,000 miles of broad-gage, 3 ft. 6-in. lines, and the same of meter-gage; this is supplemented by some 5000 miles of narrow-gage, 2 ft. 6 in. and 2 ft. Railways are not only vital in the economic development of India but are the means of distributing the food to the 350,000,000 people. Great famine funds which were provided by taxation are now being spent in further development, not only of railways but vast irrigation projects. At present the Punjab project is under way; it far exceeds anything ever undertaken in America and will make a barren desert as productive of cotton as our best southern states.

It is very gratifying to see the interest the railway men of India take in our American engineering. Just now there is a strong tendency toward our locomotive designs. I am here now in Delhi to discuss the standardization of locomotives with the Railway Board, the functions of which combine those of our Interstate Commerce Commission and the Railway Administration. They have to approve every policy of the Indian Railways, both engineering and financial. They are a very high-grade body of men, representative of the very best in India.

Conference of Women Engineers Held in England

SOME forty delegates convened by the Women's Engineering Society met at Birmingham University on April 12 and 13 in the first conference of women engineers ever held. The presidential address of Lady Parsons was followed by an outline of the history of mechanical engineering by Prof. F. W. Burstall, Dean of the Faculty of Science, Birmingham University. Professor Burstall discussed the social and ethical effects of scientific progress, stating that the human element must be the predominant issue in all matters of engineering development. He later conducted the delegates in an inspection of the engineering department of the University.

At an evening session on April 12 Miss M. Partridge, of M. Partridge & Co., domestic engineers, Exeter, read a paper based on her experience in electrical contracting work in country districts.

On April 13 a paper by Mrs. L. M. Gilbreth, whom illness prevented from being present as representative of The American Society of Mechanical Engineers, was read by Miss C. Haslett, secretary of the Women's Engineering Society. Her article was a brief exposition of the growth in the breadth of interest of the engineer, in his work, and in his field of influence.

Miss Entwisle, of the Metropolitan-Vickers Electrical Co., Ltd., Manchester, presented a paper entitled Some Considerations of Electrical Design. Mme. Laurent, who, with her husband, attended the conference as directors of the Ecole Technique Feminin de Paris, and as representatives of the French Government, gave a short lecture, illustrated with lantern slides, on the gradual development of women engineers in France. The convention closed with a trip to Stratford on Avon on April 14.

Dr. George K. Burgess Becomes Director of the Bureau of Standards

THE DIRECTORSHIP of the U. S. Bureau of Standards has recently been placed in the hands of Dr. George K. Burgess, who has been connected with the Bureau since 1903 and since 1913 has been chief of the Division of Metallurgy. His long association with the Bureau, and his intensive research work, particularly in iron and steel, make him well qualified for his new position.

Dr. Burgess was born in Newton, Mass., in 1874, received the degree of B.S. from Massachusetts Institute of Technology in 1896, held a fellowship there from 1898 to 1900, and obtained his Sc.D. from the University of Paris in 1901. He was instructor at the University of Michigan for one year, and at the University of California for two years, previous to entering the Bureau.

As a member of the National Research Council Dr. Burgess has been active in its committee work. He represents the Department of Commerce on the American Engineering Standards Committee and is this year's president of the American Society for Testing Materials.

Sir J. J. Thomson Visits America

SIR JOSEPH JOHN THOMSON, F.R.S., who has been a visitor in this country during recent weeks, was awarded the Franklin Medal at a special meeting of the American Philosophical Society in Philadelphia on April 10. He likewise received the John Scott medal and award of $1000. The subject of his address on this occasion was the possibility of a new form of water molecule.

Sir Joseph, for many years Cavendish Professor at Cambridge, and now Master of Trinity College, came here under the auspices of The Franklin Institute to give a series of lectures before that institution on The Electron in Chemistry. These lectures, with due regard to progress of science, may be said to be a continuation of those delivered by Lord Kelvin before the same body.

Sir Joseph was the speaker at the dedication of the Sterling Laboratory at New Haven on April 4, and on April 6 and 7 visited the Research Laboratory and the Schenectady Works of the General Electric Company, giving an informal talk to the laboratory staff and engineers and evidencing much interest in the work they are carrying on.

Mr. Dickinson of South Kensington Museum Visits the United States

H. W. DICKINSON, Assistant to the Director of the Science Museum at South Kensington, London, and Honorary Secretary and Treasurer of the Newcomen Society, visited New York, Washington, Philadelphia, Boston and Dayton during April and May.

Mr. Dickinson is keenly interested in the history of engineering and technology, developing interest in which is one of the important objects of the Newcomen Society. On his trip Mr. Dickinson was the guest of several groups of engineers who have displayed an appreciation of the value and importance of engineering history.

Mr. Dickinson was a speaker at the dinner celebrating the Centennial of the Delaware and Hudson Company on April 23. His topic was the early development of the steam engine.

The Engineer in Public Affairs

GANO DUNN was the presiding officer at the meeting, held May 8 in the Engineering Societies Building, devoted to the "Engineer in Public Affairs." The gathering was under the auspices of the New York Sections of the American Society of Civil Engineers, the American Institute of Mining and Metallurgical Engineers, The American Society of Mechanical Engineers, and the American Institute of Electrical Engineers. In addition there were present representatives of the Society of Municipal Engineers, Society of Automotive Engineers, American Society of Heating and Ventilating Engineers, the American Society of Safety Engineers, the Taylor Society, the Society of Illuminating Engineers, and the New York Society of Architects. The speakers of the evening were Admiral John Keeler Robison, Engineer in Chief of the United States Navy, and Frank Jewett, president of the American Institute of Electrical Engineers and Chairman of the Engineering Division of the National Research Council.

Mr. Dunn opened the meeting in the following well chosen words:

Engineers have inscribed in this Temple of Engineering, in the great library that crowns our building and the efforts of many years, the legend, "Engineering is the art of organizing men and controlling and directing the forces and materials of nature for the benefit of the human race." Now, when we come to discuss the Engineer in Public Affairs, that discussion necessarily turns our attention rather more toward the side of engineering that has received more attention in late years than ever before, the side of the engineer's generalship, the side of the engineer's organizing capacity, the side of the engineer's human contacts. There has never been a time when the demand for the education of engineers in the humanities as well as in the sciences and the technologies has been as great as it is today. There never has been a time when the demand for the education of engineers in English, in literature, in the fine arts, has been as great as it is today. The reason is an appreciation, not only on the part of engineers themselves, but on the part of those with whom they work, that an engineer must be an all-around man before he can reach the heights of engineering. The groping and straining towards a larger part in national affairs that have been concomitant with the development of the national and other engineering societies in the last twenty years has been due to the feeling within engineers themselves that their places as citizens are more and more responsible as every day goes on.

For my own part I think there has been a waning of opinion in engineering circles that has overemphasized the desirability, if not the appropriateness, of a certain extreme degree of participation of engineers in public affairs. On the other hand, the increasingly essential relation of engineering works and structures, engineering operations, engineering conceptions, and even engineering terms and habits in the daily life of the people of the United States, has been so marked that engineering of itself has been taking a greater and greater part in public affairs, and if the engineer cannot keep pace with his subject, then he certainly is unworthy of the name.

In introducing Admiral Robison, Mr. Dunn paid a tribute to the engineering service of the United States Navy and read the following engineering creed sent to Admiral Robison when he was appointed Engineer in Chief of the Navy and which served to inspire him in no small degree:

The idea of devotion to duty as a measure of worth, of worth as a measure of happiness, and of service as the proper aim of each of us, I believe to be true. Particularly do I believe that lasting happiness is found only through the medium of unselfish service. The thought of self in service, no matter how big the service, runs counter to nature's laws of compensation. Self-glorification and contentment of spirit are not found on the same trail.

Admiral Robison pointed out that the opportunity facing engineers in public service must be grasped that the common weal of the whole mass of humanity may be accomplished. Originally all engineers in public service were civil engineers. The word "civil" is a derivation meaning a man who is a "builder for the state." Today there are many specialized branches of engineering but the basic reason for the existence of any kind of engineer is that he is a builder for the state. Admiral Robison then told of the remarkable work being carried on in the engineering department of the Navy. He emphasized the fact that, if the shores of this country are to be kept unpolluted by war, the ships or our Navy must be able to take any desired position and take it first. The ships must move far enough and stay there long enough. The ability to do this is an engineering problem. The task of moving a fleet between two points involves reliable machinery and plenty of fuel. Increasing the fuel radius of the individual vessels and installing machinery of greater reliability and economy was emphasized by the Admiral as important steps in increasing the mobility of the ships. The preparation of detailed instructions in the use of fuel and the enforcement of these instructions proved to be a considerable factor in reducing the expenditures for fuel by 32.03 per cent per knot under way and 49.7 per cent per day in port.

Admiral Robison also told of the great work the United States Navy had accomplished as a humanitarian agency. In closing he emphasized the tremendous importance of the spirit of service which is not peculiarly naval. He said they are but representatives of the noblest profession in the world, builders of things and of character.

In introducing Mr. Jewett, Mr. Dunn called attention to the fact that the meeting of the evening had been organized by the Federated American Engineering Societies and that representatives of all branches of the profession were present. Mr. Dunn expressed his views about the F.A.E.S. in the following words:

The Federation is, up to date, the result of the outgrowth and the embodiment of those things in engineers which they feel can be done better united than separate.

The Federation is going through a period which confronts bodies in similar circumstances in other realms. The details of its operations and accomplishments must be ultimately that nice balance between strong opposing forces upon which the health of an organization always depends. The history of our own country illustrates that: at the beginning it was almost impossible to form the federation which was called the United States of America. Even our own New York did not sign the Declaration of Independence until three or four months after the Fourth of July.

Now, while in the ranks of engineers there is not today that agreement which many of us would like to see, I think if we all stand off a distance and look, we will get a perspective that will be of great value. I hold these principles to be self-evident, that engineers cannot continue to go on as entirely separate and distinct organizations, that there is something in the human side of all the engineering branches that needs contact with other branches, and that there is an as yet undeveloped force and power among engineers as a profession that, if properly united, polarized and made to pull all one way, can speak for engineers, can represent them, and can make them a force in the community that they have not as yet been made.

Now, these things being so, it is not a question of whether or not engineers shall federate; they are already federated; this meeting tonight illustrates it. It is only a question of the details that that federation shall take, and, therefore, I think we can pay no greater tribute to the engineers as a profession than by adopting the confident belief that some kind of federation is a necessity, and that some kind of useful, successful, and effective federation is absolutely bound to come.

Mr. Jewett in his address further emphasized the belief that some sort of joint organization of engineers is necessary and that an effective federation should be developed in the future.

Los Angeles Regional Meeting

THE highly successful Los Angeles Regional Meeting on April 16 through 18, 1923, was reported in brief in the May 7 issue of the A.S.M.E. NEWS. We received the corrected stenographic report of the excellent dinner addresses and the discussion at the technical session too late to give the proper space in this issue. They will be used in later issues of MECHANICAL ENGINEERING.

Engineering Index and Library Combine to Serve Engineer

REFERENCE was made in the preceding issue of MECHANICAL ENGINEERING to statements by Prof. W. Trinks in regard to technical literature. The paucity and inadequacy of engineering libraries in the country to which he calls attention need not be a serious problem for engineers in country districts if the following points are noted.

Back of The Engineering Index for 1922, which has just been issued, is the Engineering Societies Library of New York, from which may be obtained, at a nominal cost, photostatic reproductions of the text of any article indexed.

Some thirty per cent of the periodicals indexed in this volume are in foreign languages. The Library will furnish translations of articles from any of these. The list of bibliographies in this volume is more extended than in preceding years. Mr. Raymond Brown of the Library Staff assisted in the compilation of this list.

The Engineering Index is not an exhaustive guide to the engineering literature of the world but it does index what are considered the leading articles on the newest developments of the year. The services of the Engineering Societies Library are prompt and efficient. The combination should be of unequalled value to engineers, engineering students, and research workers everywhere.

Engineering and Industrial Standardization

Standardization of Mathematical and Graphical Symbols and Abbreviations

A RECENT conference held in New York under the auspices of the American Engineering Standards Committee revealed sentiment among engineers, scientists, government officials, business-paper editors and industrial executives emphatically in favor of the unification of technical and scientific abbreviations and symbols.

It was agreed on all sides that the standardization of abbreviations and symbols would result in inestimable mental economies. The present situation with respect to the use of abbreviations and symbols in engineering, scientific, and other technical fields is comparable to a language which has degenerated into a multiplicity of dialects, each of which has to be translated for the users of the others. Abbreviations and symbols constitute an ever-growing and important part of the language of engineers, scientists, industrial editors, and other technical men. The use of one symbol or abbreviation for several different terms and the use of several different symbols or abbreviations for one meaning are, however, at present causing a great deal of confusion, misunderstanding, and often serious errors.

The conference was called upon requests from the American Institute of Electrical Engineers, The American Society of Mechanical Engineers, and the Association of Edison Illuminating Companies to consider abbreviations and mathematical symbols, but after some discussion of the subject it was thought desirable to include as a part of the project the graphical symbols which are used in engineering drawings, diagrams, and the like, for representing instruments and apparatus and their components.

It was agreed that the coöperation of foreign standardizing bodies should be sought in the development of the work. The importance of international uniformity in symbols is great on account of the international character of much engineering and scientific work, and the importance of reference books and periodicals in foreign languages.

The work will go forward under a Sectional Committee organization developed in accordance with the rules and procedure of the American Engineering Standards Committee.

Recent Progress in Standardization of Particular Interest to Mechanical Engineers

Walkway Surfaces. The American Engineering Standards Committee has invited the American Institute of Architects and the American Society of Safety Engineers to act as joint sponsors for the proposed safety code on walkway surfaces.

Petroleum Products and Lubricants. Standard methods of testing petroleum products and lubricants will be developed by a sectional committee organized under the sponsorship of the American Society for Testing Materials as a result of recent action by the A.E.S.C.

Flash Point of Volatile Flammable Liquids. The A.E.S.C. has approved as "Tentative American Standard" the standard method of test for flash point of volatile flammable liquids submitted by the American Society for Testing Materials. The A.S.T.M. has been appointed sponsor for this standard, and in this capacity will publish the standard and direct any revision of it that may later be necessary.

Radio Apparatus. Sponsorship for radio standardization has been assigned by the American Engineering Standards Committee to the Institute of Radio Engineers and the American Institute of Electrical Engineers, jointly. This action was taken in accordance with the recommendations of the large representative conference called by the Bureau of Standards.

Safety Code for Forging Industry. The formulation of a national safety code for the forging industry will be undertaken immediately as a result of the decision of a conference of the principal organizations interested in the subject recently held in New York on the call of the A.E.S.C., under whose procedure the code will be developed.

The conference by resolution requested that the code include the hazards of drop forging and other hammer forging, as well as all hazards peculiar to the forging industry and associated with the machines used in the industry whether or not they occur at the point of operation. The same resolution suggested that the code do *not* include the hazards of cold extrusion of non-ferrous metals, or hydraulic presses, except as the Sectional Committee may find it desirable to include small types of the latter and that the inclusion of hot pressing, bulldozing, and other forging operations, such as those of bolt-heading and rivet-making machines, be left to the discretion of the Sectional Committee.

Colors for Traffic Signals. Forty-two men, representing the manufacturers and users of traffic signals, federal and state governmental departments, associations interested in the prevention of traffic accidents, and representatives of the general public, are now at work on the drafting of a national code on the proper colors for traffic signals, which it is expected will not only cut down the annual loss of life through traffic accidents, but will eliminate any of the existing irritations to motorists and to the operators of steam and electric railways.

This work is being carried on under the auspices of the A.E.S.C. whose approval of a code or standard insures its ultimate acceptance and observance throughout the country. The Sectional Committee drafting this code is made up of seven representatives of the manufacturers of traffic signals, nine representatives of the purchasers of such equipment, three representatives of the users of traffic signals, twelve representatives of governmental bodies, five technical specialists, and six insurance representatives. The American Engineering Standards Committee is composed of seven departments of the U. S. Government, the principal technical, industrial, and engineering societies, and individual business concerns interested in standardization.

Six Electric-Railway Rail Standards. The A.E.S.C. has approved as "American Standard" six of thirteen specifications covering the design of steel rails and their accessories, which have been submitted by the American Electric Railway Association, one of the pioneers in industrial and engineering standardization. Considerable progress has been made in the consideration of the remaining specifications.

The specifications which have been approved cover the design of the following: Nine-Inch Girder Grooved Rail; Seven-Inch Girder Grooved Rail; Nine-Inch Girder Guard Rail; Seven-Inch Girder Guard Rail; Joint Plates for Seven-Inch Girder Grooved and Girder Guard Rails; and Joint Plates for Nine-Inch Girder Grooved and Girder Guard Rails. Some of these specifications were adopted as standard by the A.E.R.A. as far back as 1907. The extent to which they have come into general use is indicated by the fact that one of the principal manufacturers of steel rails reports that approximately 79 per cent of his total tonnage of girder rails shipped to electric railways during 1922 was A.E.R.A. standard. This same company reports that during the past seven years 62 per cent of its total tonnage of electric-railway girder rails was A.E.R.A. standard.

Code on School Lighting. The lighting, building, education, health, and social agencies of the country have joined hands in an effort to develop a nationally accepted code for school lighting which will correct the conditions partially responsible for the defective vision of 10 to 20 per cent of the school children. The A.E.S.C. has appointed the American Institute of Architects and the Illuminating Engineering Society joint sponsors for a Code on School Lighting. The sponsors will organize a representative sectional committee to formulate the code and will provide for the publication of the code after it has been approved by the A.E.S.C.

Standardization in Denmark. The A.S.M.E.'s correspondent in Berlin reports as follows: "According to the Danish newspaper *Ingeniören* Nr. 2 of January 13, 1923, the Standardization Committee of that country held a meeting on December 12, 1922,

at which the question of coöperation with other national standardization committees was discussed. During this discussion it was pointed out that if it is a question of coöperating with one country, that country would most likely be Germany, as working with England is impossible on account of the inch system of measures in use there. A complete adherence to German standards may, however, easily lead to dependency; the more so as there is hardly any Danish export of industrial products to Germany."

Although it may readily be admitted that the German standards will be worked out perfectly, it is on the other hand almost certain that small Denmark will have no influence on such standardization. It was finally agreed, therefore, to strive for the creation of Inter-scandinavian Standards by Finland, Norway, Sweden, and Denmark.

Ice-Cooled Domestic Refrigerators. The American Institute of Architects has requested the A.E.S.C. to arrange for a national conference of all interests involved to consider the desirability and feasibility of establishing standards for ice-cooled domestic refrigerators both as to size and cooling per pound of ice melted. The American Institute of Architects is prompted to make this request by the belief that it is both desirable and feasible to establish a standard rating for domestic refrigerators, based upon thermal conductivity. There are, of course, many other features of design and construction affecting refrigerator efficiency which should be considered. There is today no criterion for ice-box efficiency by which either the public or the architectural profession may judge of values in terms of ice economy and food preservation. There is a wide variation in the chilling effect of the melting of a pound of ice in the various types and makes of domestic refrigerators now on the market. Some of them are practically worthless. Not only are they wasteful of ice, but they also constitute a menace to health in that they do not preserve the food placed in them.

Sizes for U. S. Flags. Most every one assumes when they buy a flag that it is an exact replica of "Old Glory." True, it has 13 stripes and 48 stars, but the size may be one of several hundred that do not conform to Government standards. On October 23, 1922, flag manufacturers met in conference with representatives of the Army and Navy, and others interested, to determine upon a method for establishing flag sizes which would be comparatively few in number and, moreover, would conform to the standards acceptable to our Government. An executive order by President Wilson in 1916 set up 12 sizes as standards for United States flags, and it is upon the basis of this, together with a survey by the manufacturers, that a subsequent conference is contemplated for the final adoption of national standards for flag sizes.

The Late Dr. Schuyler Skaats Wheeler

A LEADING inventor and engineer in the electrical field, Dr. Schuyler Skaats Wheeler, died suddenly of angina pectoris on April 20, 1923, in the sixty-third year of his age. Dr. Wheeler was born in New York and was graduated from Columbia University in 1881. After a few minor connections he became a member of the staff of Thomas A. Edison, and for three years was engaged in installation work. From 1886 to 1888 he was connected with the C. & C. Motor Co., which he helped to organize.

In 1888, the Crocker-Wheeler Company, of New York and Ampere, N. J., was formed with Dr. Wheeler as president, a position which he occupied up to the time of his death. This company was the first in the world to manufacture small electric motors, and during the past thirty-five years has installed more than 1000 electric drives designed by Dr. Wheeler.

Dr. Wheeler was an organizer and founder of the United Engineering Societies, and was a member of the national, civil, electrical, and mechanical engineering societies. He was for a time president of the American Institute of Electrical Engineers, to which he gave the Latimer-Clark library, said to be the largest collection of rare electrical books in existence. He became a member of The American Society of Mechanical Engineers in 1899.

Water-Power Resources of Canada

WATER power is one of Canada's most basic and valued natural resources. The capital invested in this development, well over half a billion dollars, makes it also one of her greatest single industries. The Water Power Branch of the Canadian Department of the Interior has for the past three years been collecting and analyzing data, and in a recent report presented some of its results.

The known available water power in Canada is 18,255,000 hp. for conditions of ordinary minimum flow and 32,076,000 hp. under a flow of estimated maximum development, that is, dependable for at least six months of the year. These estimates have been made on the basis of 24-hr. power at 80 per cent efficiency. The ordinary minimum flow is based on the averages of the minimum flow for the lowest two consecutive seven-day periods in each year over the period for which records are available. The estimated flow for maximum development is based upon the continuous power indicated by the flow of the stream for six months in the year.

The Interior Department believes that these are conservative estimates since an analysis of existing water-power plants scattered from coast to coast, concerning which complete data are available as to turbine installation as well as satisfactory information regarding stream flow, gives an average machine installation 30 per cent greater than the six-months'-flow maximum power. Applying this to figures quoted above indicates that the present recorded waterpower resources of Canada will permit a turbine installation of 41,700,000 hp.

The total capacity of the water wheels and turbines installed is 2,973,759 hp. or 338 hp. per thousand population. Canada's position is second only to that of Norway in the per capita utilization of water power.

In the central-station industry in which there is an installed turbine capacity of 2,204,486 hp., 1,556,956 hp. is installed in privately owned stations and 647,530 hp. in publicly owned stations.

Pulp and paper manufacturing is a typical and preëminent Canadian industry with a future of almost unlimited prosperity ahead of it, the result of two natural advantages of almost equal moment, namely, an abundant supply of growing pulpwood and cheap accessible motive power in large quantities. The importance of cheap power lies in the fact that it takes practically 100 hp. to produce one ton of paper per day. It is not surprising, therefore, that the motive power used in this industry is almost altogether restricted to hydraulic energy and that Canada's premier advantage and position in the pulp and paper field rest on adequate and abundant water power well distributed among extensive forest reserves.

Water power is operating 113 pulp and paper mills in Canada, 664,805 hp. being employed. Of this total, 482,228 hp. is actually installed in connection with the mills and 160,577 hp. is purchased from hydroelectric central stations.

The innovation of the electric drive is having a marked and favorable influence on pulp and paper manufacturing processes. It makes possible the centralized operation of fewer and larger mills receiving power from several power sites, together with the further advantages of uniform speed and better control in grinding, thus lessening costs of operation, construction, and shipping. Of the 484,228 hp. actually installed in pulp and paper mills 183,311 hp. is used in the electric drive, besides which there is 160,577 hp. of hydroelectric energy purchased from central stations, thus bringing the total horsepower that is employed in the electric drive up to 343,888.

The water power now developed in Canada represents an investment of over $620,000,000. In 1940, should the rate of growth in installation during the past fifteen years be continued, this investment will have grown to over $1,100,000,000. The present development represents an annual equivalent of 26,700,000 tons of coal, which, valued at $10 per ton, represents $267,000,000. In the year 1940 these annual figures will, with the foregoing assumption, have become 50,000,000 tons and $500,000,000, respectively.

Meetings of Other Societies

American Society of Civil Engineers

The river and harbor problems of the lower Mississippi was the general subject under discussion at the spring meeting of the American Society of Civil Engineers held at New Orleans, April 18–20, 1923. A number of the eleven papers presented at the two technical sessions dealt with navigation control and operation, and the others with flood control. Maj. L. H. Beach, chief U. S. Corps of Engineers, described the work of the Engineers' Corps on the Lower Mississippi, A. L. Dabney, consulting hydraulic engineer, the success of the levees during the flood of 1922, and L. H. Parmelee, consulting engineer, Helena, Ark., the high-water fight at Old Town, Ark., in 1922.

The economic location of jetties was discussed by Henry C. Ripley, consulting engineer, Detroit, Mich., and river control by John Klorer, city engineer of New Orleans. Transportation on the Mississippi River was the subject considered by two speakers, M. J. Sanders, manager of the International Mercantile Marine and the Frederick Leyland Company, Ltd., New Orleans, La., and the Hon. Joseph E. Ransdell, U. S. Senator from Louisiana. The former took up the question of the revival of commercial transportation, and the latter spoke on the economics of transportation.

The port problem was also the subject of two papers, presented by John F. Coleman and Samuel M. Young, both of whom are associated with the Board of Port Commissioners, New Orleans. Elliott J. Dent, Lt-Col., U. S. Corps of Engineers, presented a paper entitled The Mouths of the Mississippi River.

John R. Freeman, a past-president of the society and now consulting hydraulic engineer, Providence, R. I., pointed out the necessity of an experimental hydraulic laboratory for the solution of river problems. Mr. Freeman discussed the present state of knowledge of river hydraulics, described the few experimental laboratories of the kind sought, and the suggested design for the one proposed in Senator Ransdell's bill presented at the last session of Congress.

An all-day excursion by steamer to points of interest in New Orleans Harbor, Inner Harbor Canal, and Lake Pontchartrain gave the members an opportunity to study conditions for themselves. The trip covered the entire harbor frontage of the Mississippi River on both sides.

Previous to the meeting the Board of Direction held a two-day session. Among the items of business transacted was the authorization of a committee of five to confer with other national societies looking toward coöperation in matters of interest in public affairs; the approval of the recommendations for Government reorganization, particularly of those tending to divorce civilian engineering activities of the Government from engineering duties which are under military control; and the acceptance of two grants from Engineering Foundation, one of $1000 for the investigation of concrete and reinforced-concrete arches, and the other of $4000 for the investigation of steel columns.

The next meeting, on the subject of highways, will be held in Richmond, Va., sometime in October.

Society of Industrial Engineers

The major subject of the tenth annual convention of the Society of Industrial Engineers, held in Cincinnati, April 18 to 20, 1923, was the effective management of the moderate-sized plant. Prof. Joseph W. Roe, president of the society, who spoke on Three Phases of Management: Financial, Sales, and Production, at the opening session, stated that although the large plant had a great advantage over the small one in the field of purchases and sales, in actual production the small plant could frequently compete with the large one on even or on better terms.

Speaking at a meeting of the educational group of the society on Economics and the Smaller Plants, Ernest F. Du Brul, general manager of the Machine Tool Builders' Association, presented figures from the Census of Manufacturers, 1919, which he believes verify statistically the economic principle that the division of labor is an economic benefit, not only in increasing product per man but also in increasing profit until a point of maximum efficiency is reached. Mr. Du Brul therefore advocates the concentration of industry in larger establishments.

Meetings of the production and personnel groups were also held. Chester B. Lord, industrial engineer, National Automatic Tool Co., Richmond, Ind., addressing the former on Production Control Systems for the Special Order Shop, and J. J. Davis, Paine Lumber Co., Oshkosh, Wis, the latter group.

Chief among the general sessions was that given over to a discussion of workers' participation in management. The workers' side was presented by John P. Frey, editor of the *International Molders' Journal;* the employers' side by Charles R. Hook, general manager, American Rolling Mill Co., Middletown, Ohio (read in his absence by M. E. Danford, of the same company); and the engineers' side by John Calder, consulting engineer, Lexington, Mass. Daniel Bloomfield, Boston, editor of *Industrial Relations,* gave a summary of surveys of 500 plans of employee representation made by him during the past few years.

Mr. Frey attributed 81 per cent of the waste in industry to management, 9 per cent to labor, and 10 to subsidiary causes. He believed that the only way waste could be eliminated was for the management, the efficiency engineer, and the workmen to get together to discuss and handle the various problems.

Mr. Hook's paper described the organization and functions of an advisory committee system in force in his organization for many years. He emphasized the importance of a proper understanding of the motives actuating the management of the business, and pointed out the benefits to be derived from a coöperative scheme which builds confidence and satisfaction on both sides.

Mr. Calder spoke for an organized representation allowing the worker a voice in the management where it touches him most closely. "Most workers," he stated, "want to count in management solely when their personal interests are concerned, and he is a wise manager who begins industrial relations there."

American Gear Manufacturers' Association

Progress in the standardization of gears, as evidenced by reports presented at the seventh annual meeting of the American Gear Manufacturers' Association, held in Cleveland, April 19–21, 1923, is indicative of a great deal of study and a fine spirit of coöperation on the part of the members of the standardization committees. One of the most important of these reports was that of the bevel- and spiral bevel-gear committee concerning a new system of bevel gears which has been worked out at the Gleason Works, Rochester, N. Y. The proposed system was adopted by the association as recommended practice for future design.

B. F. Waterman, chairman of the general standardization committee, summarized the work of the various sub-committees. He advocated that the recommendation of the worm-gear committee, which tended to eliminate the great diversity of hob sizes necessitated by the variance in customers' specifications, be tried out for six months, after which definite action might be taken. He announced a recommendation to be submitted by the metallurgical committee, covering the heat treatment of A.G.M.A. steels, and a forthcoming report on the nomenclature of gears. The proposed tentative American standards which have been submitted include gears and pinions for electric railroad service, gray-iron industrial spur gears, specifications for forged and rolled steel for gears, specifications for cast steel for gears, and specifications for brass and bronze for gears. During a general discussion of various phases of standardization, it was urged that the association should standardize tooth curves, that inspection should start with tooth curves, and that tooth forms for large-sized bevel gears should be standardized.

The report of the association's representatives on the A.S.M.E. research committee on gears stated that the special gear-testing machine designed by Wilfred Lewis had been found to warrant development, and that Ralph E. Flanders, of the Jones & Lamson Machine Co., had been authorized to solicit subscriptions from those interested in this research work.

Among the technical papers presented was one on Grinding and Measuring Involute Gear Teeth, by E. J. Lees, Lees-Bradner Co., Cleveland; one by Wilfred Lewis describing the special gear-testing machine of his design; one on Tooth Forms of Automobile Gears after Cutting, Hardening, and Grinding, by K. L. Hermann,

of the Studebaker Corpn., emphasizing that quietness depends upon the accuracy with which gears are cut; and one by S. P. Rockwell, metallurgical engineer, of Hartford, Conn., who was appointed metallurgist for the association. Mr. Rockwell dealt with the determination of grade of steel by observation of the characteristics of the spark when the sample is held against an abrasive wheel, and gave actual demonstrations to show the difference in the spark produced in the grinding operation with the use of samples of different carbon analysis.

Industrial relations, labor shortage, and cost accounting were among other subjects discussed at the meeting. Geo. L. Markland, Jr., of the Philadelphia Gear Works, was elected president to succeed F. W. Sinram, who has held the office since the formation of the organization in 1917. Mr. Sinram was elected honorary president for life.

Progress of Coal-Storage Campaign

ONE OF THE first companies to follow the lead of the Connecticut Company in aiding employees to secure their full supply of coal early in the season is the Adirondack Power & Light Co., of Schenectady, N. Y. Upon receipt of the outline of the Storrs Plan from the Federated American Engineering Societies, this company, of which C. S. Ruffner is general manager, sent a communication to all its employees which read in part as follows:

In districts where this company sells coke from its gas plants a plan will be published offering special inducements to employees and to the public to purchase coke for their next winter's requirments, for delivery during the period from April 1 to September 1.

For all districts there will be made arrangements whereby any employee may submit by April 15 an estimate of his winter fuel needs; the list of such individual orders will be placed with any dealer selected by a committee consisting of the resident manager and two other employees who desire to purchase fuel by this plan. Delivery to be made at the dealer's convenience any time before September 1. When delivery is made the company will, if requested by the employee, pay the dealer in fullf or fuel delivered, and will be reimbursed by deducting that amount from the employee's salary thereafter in equal installments in each of the next four months after delivery. The company will not buy and sell the fuel but will only guarantee cash payments to the dealer, and will carry the account for the employee as above stated.

Under this plan fuel can be purchased at the best possible price, deliveries can be scheduled advantageously, dealers will be influenced to deliver the maximum amounts early in the season, and employees who have been accustomed to buying coal in small lots during the period of highest prices can make substantial savings and be assured of a sufficient quantity of coal when needed and without severe burdens of prepayment. Employees will be encouraged to enlarge their storage facilities to hold their whole winter's requirements.

Nearly 170 employees of the company (about 10 per cent of the total number) have already ordered coal and coke amounting to over 800 tons, the orders being placed with local dealers at current prices.

The Westinghouse Electric & Manufacturing Co. reports that it is making a study of the plan which will be put into operation if found feasible for their organization. Other companies are desirous of developing their own plans, based upon the Storrs Plan.

Meanwhile the F.A.E.S. Committee on Coal Storage has been organizing. Those who have already accepted appointment on the committee are: W. L. Abbott, chief operating engineer of the Commonwealth Edison Co., Chicago, chairman; P. F. Walker, dean of engineering, University of Kansas; S. W. Parr, professor of applied chemistry, University of Illinois; H. Foster Bain, Director of the U. S. Bureau of Mines, and L. E. Young, Union Light Power Co., St. Louis.

The chairman of this committee has had large experience in the successful storage of coal, having collaborated with Dr. Stock in much of his pioneer work. Professor Parr and Mr. Young had also worked extensively with Dr. Stock in developing ways and means of effective storage of coal. Professor Parr has a national reputation as a coal chemist. Mr. Young has had wide and responsible engineering experience and is also accomplished in accounting and economics. Dean Walker is especially familiar with the transportation and industrial conditions that will enter into this study. Dr. Bain, as Director of the Bureau of Mines, is in intimate touch with all that the Government has done with this subject.

A bibliography of the subject is already in course of preparation, as well as a compilation of data and records that have already been made by other organizations that will relate to this subject in various ways.

LIBRARY NOTES AND BOOK REVIEWS

AMERICAN PETROLEUM REFINING. By H. S. Bell. D. Van Nostrand, New York, 1923. Cloth, 6 × 9 in., 456 pp., illus., diagrams, $5.

The first American book exclusively devoted to refining. Discusses the manufacturing process, the arrangement of refineries, the apparatus and treatment used, the storage and transportation of oil, etc. Intended to give the fundamental information needed by those about to erect refineries or by those engaged in the industry who wish a picture of it as a whole.

AUTOMOTIVE REPAIR. Vol. 3, For Battery Service Men; vol. 4, For Tire Service Men. By J. C. Wright. John Wiley & Sons, New York; Chapman & Hall, London, 1923. Cloth, 6 × 9 in., vol. 3, 387 pp.; vol. 4, 305 pp.; illus., tables, $3 each.

These two volumes complete this extensive work on the repair of automobiles by presenting methods for repairing tires and batteries. They follow the plan of the earlier volumes in giving for each job, first, an outline of the necessary operations, then the materials, tools and parts required and, finally, a detailed description of the method. The reasons for each operation are also given. The directions are clear and practical, and cover almost every emergency that can arise.

DIE DAMPFTURBINEN. Vol. 1; Theorie der Dampfturbinen. By Const. Zietemann. Walter de Gruyter & Co., Berlin and Leipzig, 1923. Boards, 4 × 6 in., 150 pp., diagrams, $0.25.

The first portion of a three-volume work on steam turbines which is intended to give not only the theory and thermal calculations, but also practical information on design and construction, and an account of present practice. The work is designed as a concise introduction for students and practicing engineers.

The present volume is concerned chiefly with theory. The fundamental laws of heat, the properties of steam and its flow through orifices are explained. The utilization of the energy of steam in turbines, including methods of reducing speed, is next considered, and this is followed by a discussion of losses in the turbine, efficiency, and power. The final section treats of steam, heat, and fuel consumption.

ELEKTROTECHNIK. Vol. 4; Die Erzeugung und Verteilung der Elektrischen Energie. By Immanuel Hermann. Walter de Gruyter & Co., Berlin and Leipzig, 1923. Boards, 4 × 6 in., 138 pp., illus., diagrams, $0.25.

One of a series of small volumes giving an outline of electrical engineering in greatly condensed form. The present volume is concerned with the generation and distribution of electricity and discusses in five chapters power plants, methods of distribution, switch apparatus, distributing networks, and the cost of electric power.

ELEMENTS OF APPLIED PHYSICS. By Alpheus W. Smith. First edition. McGraw-Hill Book Co., New York and London, 1923. Cloth, 6 × 9 in., 483 pp., illus., diagrams, $3.

Prepared for students who are primarily interested in the practical applications of physics, this book has been written with their training and habits of thought in mind and includes those topics that they can assimilate thoroughly. A large number of illustrations of the applications of physics to engineering and every-day life are given in an effort to stimulate the student to recognize the universality of physical laws and to find in them the explanation of everyday experiences.

FLUSSIGKEITSBEHALTER. ROHREN, KANALE. Vol. 5, Handbuch fur Eisenbetonbau. By F. Emperger. Third edition. Wilheim Ernst & Sohn, Berlin, 1923. Paper, 7 × 11 in., 409 pp., illus., diagrams, tables. $3.24.

Volume 5 of Emperger's well-known handbook has reached the third edition. It contains two chapters, one upon tanks for liquids, the other upon pipes, open conduits, aqueducts, and canal bridges. The first of these chapters has been entirely rewritten by Dr. Löser, Dr. Grün and Dr. Lewe. It now includes the experience resulting from the extended use of concrete tanks for many purposes since the appearance of the second edition in 1910. The composition of waterproof concrete, waterproofing compounds and paints, and the chemical effects of various liquids are discussed in detail. Similar detailed attention is given to the statics of tank construction, where an attempt is made to set forth modern methods of calculation in an easily understood form and to illustrate them by numerous examples. The chapter on pipes and conduits has been thoroughly revised by F. Lorey, in the light of recent experience and modern structures.

FOUR LECTURES ON RELATIVITY AND SPACE. By Charles Proteus Steinmetz. First edition. McGraw-Hill Book Co., New York and London, 1923. Cloth, 6 × 9 in., 126 pp., diagrams, plates in pocket, $2.

In these lectures the extensive use of mathematics has been avoided. Dr. Steinmetz has attempted to give the layman and the engineer who is not an expert mathematician a general knowledge and understanding of the new ideas of time, space, the laws of nature and the characteristics of the universe which the relativity theory has deduced, and of the researches on which the theory rests.

GAS UND WASSERVERSORGUNG DER GEBAUDE. By Wilhelm Schwaab. Walter de Gruyter & Co., Berlin and Leipzig, 1923. Boards, 4 × 6 in., 121 pp., illus., $0.25.

The purpose of this little volume is to give those interested in gas and water installations in buildings a concise bird's-eye view of the subject. The first division of the work treats of gas, describing its manufacture, the method of distributing it and of installing the piping in the building, and its use for lighting, heating, etc. The second section of the work discusses the water supply in a similar way.

HANDBOOK OF BUSINESS CORRESPONDENCE. By S. Roland Hall. McGraw-Hill Book Co., New York and London, 1923. Fabrikoid, 5 × 8 in., 1048 pp., illus., $5.

A small encyclopedia for advertisers and for business men generally, by an experienced manager of sales. Describes the organization of a mail-sales division, methods of caring for dictation, processes for printing and reproducing letters. Gives advice on the composition of letters for various purposes—selling, collecting, adjusting, etc.,—or to various kinds of people, and illustrates this advice by numerous models.

HANDBOOK OF STEEL ERECTION. By M. C. Bland. First edition. McGraw-Hill Book Co., New York and London, 1923. Fabricoid, 4 × 7 in., 241 pp., tables. $5.

A pocketbook for engineers and contractors. Section one reviews briefly the ordinary methods for erecting bridges, buildings, standpipes and other structures. Section two, on equipment, contains numerous examples illustrating the design of ordinary appliances and data for finding the wheel and outrigger loads of locomotive cranes and derrick cars. Section three gives the detailed computations for several representative problems in the erection of bridges and buildings. Section four consists of mathematical tables.

HEIZUNG UND LUFTUNG. Vol. 1; Das Wesen und die Berechnung der Heizungs- und Luftungsanlagen. By Johannes Körting. Walter de Gruyter & Co., Berlin and Leipzig, 1922. Boards, 4 × 6 in., 139 pp., diagrams, $0.25.

A concise guide for students of heating and ventilation. Deals with theoretical principles, rather than practical details.

HISTORY OF THE THEORY OF NUMBERS. Vol. 3, Quadratic and Higher Forms. By Leonard E. Dickson. Carnegie Institution of Washington, Washington, D. C., 1923. Paper, 7 × 10 in., 313 pp., $3.25.

The third volume of this exhaustive history treats of the arithmetical theory of forms and is concerned mainly with general theories rather than with special problems and special theorems. The investigations here in question are largely those of leading experts and deal with the most advanced parts of the theory of numbers. Many of the papers are so recent that all previous reports and treatises are entirely out of date. Every effort has been made to make the list of references complete.

INDUSTRIAL FURNACES. Vol. 1. By Willibald Trinks. John Wiley & Sons, New York; Chapman & Hall, London, 1923. Cloth, 6 × 9 in., 319 pp., diagrams, $4.50.

This volume deals with the fundamental principles that underly all industrial heating operations and furnace design, and with those applications which are independent of the kind of fuel or energy supply. The principal subjects discussed are the heating capacity and fuel economy of furnaces, heat-saving appliances in combustion furnaces, furnace strength, and durability, and the movement of gases in furnaces. A succeeding volume will treat of specific applications of furnaces.

The book is based on articles published in the *Blast Furnace and Steel Plant* and the *American Drop Forger*, revised and expanded.

INDUSTRIAL ORGANIC CHEMISTRY. By Samuel P. Sadtler and L. J. Matos. Fifth edition. J. B. Lippincott Co., London and Philadelphia, 1923. Cloth, 6 × 9 in., 691 pp., illus., diagrams, tables, $8.

The fifth edition of this well-known treatise follows the general plan of the preceding ones, but it has been thoroughly revised and to a considerable extent rewritten. Within a single volume of moderate size, it takes up a number of the more important industries or groups of industries based upon organic chemistry, and shows the existing conditions in them. This is done in language that can be understood even by those who are not specially trained in chemistry.

In taking up the several industries, the raw materials are first enumerated and described. The processes of manufacture are then outlined and explained, and the intermediate and final products are characterized. The analytical tests and methods used to control the processes or to determine the purity of the products are then given. A bibliography is appended to each chapter.

INDUSTRIAL ORGANIZATION. By Malcolm Keir. Ronald Press, New York, 1923. Cloth, 6 × 9 in., 421 pp., $2.75.

The author of this work believes that many persons find economics difficult and uninteresting because they have little conception of the complex industrial order by which the ordinary necessaries of life reach the consumer or of the complete organization of our national business life. This interesting volume is intended to supply such a background of facts about our industrial organization, to present a picture in perspective of the interlocking factors of our industrial life, and thus to make it possible for the reader to understand and appreciate theoretical economics.

NICKEL. By F. B. H. White. Isaac Pitman & Sons, London and New York, 1923. (Pitman's Common Commodities and Industries.) Cloth, 5 × 7 in., 118 pp., illus., tables. $1.

A brief account of the occurrence of nickel, the methods for recovering and refining it, and the uses of the metal and its alloys. Written in simple style and intended for readers who are not specialists, but who wish general information.

PRINTING TELEGRAPH SYSTEMS AND MECHANISMS. By H. H. Harrison. Longmans, Green & Co., New York and London, 1923. (Manuals of telegraph and telephone engineering.) Cloth, 6 × 9 in., 435 pp., diagrams, $7.

Intended as a reference book for designers of telegraph machinery and as a textbook for those engaged in telegraphy, this book is a comprehensive study of the principles and mechanisms which are involved in p inting telegraphs and a history of the development of the art.

RAILROAD FREIGHT TRANSPORTATION. By L. F. Loree. D. Appleton & Co., New York and London, 1923. Cloth, 5 × 8 in., 771 pp., illus., diagrams, map. $5.

All of the functions of a railroad arise from and focus in transportation. As they have become highly specialized, the functions of each department have found exposition in many books. But no book has been written immediately concerned with transportation, the reason for the existence of the railroads. It is the purpose of

this book to assemble in reasoned order all of the phases of loading, distribution of cars, movement of engines and trains, handling of men, the features of permanent way and shop plant, the organization through which they are controlled, and the accounting made of their activities—as they are related to transportation. It is concerned with all that enters into freight transportation.—*Preface.*

SEWERAGE: The Designing, Constructing and Maintaining of Sewerage Systems and Sewage Treatment Plants. By A. Prescott Folwell. Ninth edition. John Wiley & Sons, New York; Chapman & Hall, London, 1922. Cloth, 6 × 9 in., 477 pp., illus., diagrams, tables, $4.

Intended as a reference book for city engineers and as a textbook for students. The present edition has been revised to include new developments since the publication of the eighth edition, while at the same time the space devoted to methods that are disappearing has been reduced. The volume includes a list of all the plants for treating sewage in the United States.

THERMODYNAMICS AND THE FREE ENERGY OF CHEMICAL SUBSTANCES. By Gilbert Newton Lewis and Merle Randall. McGraw-Hill Book Co., New York and London, 1923. Cloth, 6 × 9 in., 653 pp., tables. $5.

The authors have attempted to meet the needs of three classes of readers: first, the beginner who wishes to learn what thermodynamics is and what kinds of problems in physics, chemistry and engineering can be solved by its aid; second, the reader who looks for the philosophical implications of such concepts as energy and entropy; third, the investigator who seeks the specific thermodynamic methods which are applicable to the problem of pure or applied science which he has attacked and the data required for its solution. The book is not a textbook in the ordinary sense of the word, although the authors trust that it will be useful in advanced chemical courses. It is designed rather as an introduction to research and as a guide to anyone who wishes to use thermodynamics in productive work.

WAVELENGTH TABLES FOR SPECTRUM ANALYSIS. By F. Twyman. Adam Hilger, London, 1923. Cloth, 6 × 9 in., 106 pp., tables, 7s. 6d.

This book is a collection of wave-length tables intended for use in the laboratory and containing only matter essential for this purpose. It is of a convenient size and weight. It includes standard wave-lengths from 2375 to 8495 I.A., the persistent and sensitive lines of most of the elements arranged under the names of the elements, and the most persistent and sensitive lines rearranged in order to wave-lengths. There is also a list of wavel-engths useful in the determination of stellar radial velocities. The values are from the most competent authorities and the source of each is carefully indicated.

Important to A.S.M.E. Members Interested in Stress Analysis

AT THE 1922 Annual Meeting, under the auspices of the Railroad Division, an extremely valuable paper dealing with stresses in locomotive frames was presented by R. Eksergian. The paper gives a lengthy and complete discussion of the analytical methods to be followed in determining stresses in locomotive frames.

In view of the fact that there was a great wealth of material presented at the last Annual Meeting and that the Committee on Publication and Papers was compelled to reduce the size of Transactions to the minimum, it was decided to omit Mr. Eksergian's paper from the annual volume, but to print pamphlet copies of the complete paper with the discussion on it, and supply copies to members who might desire to have them. The number of copies printed will be limited to the number of requests for it received before September 1. Requests for this pamphlet should therefore be sent to the Secretary's office before that date.

A synopsis of the paper follows. Members of the Society are requested to study this carefully and determine whether the subject-matter would be of value in their work. It may be stated that the analytical methods developed by Mr. Eksergian should prove of value to all engineers engaged in the study of stresses howsoever set up.

SYNOPSIS OF R. EKSERGIAN'S PAPER ON STRESSES IN LOCOMOTIVE FRAMES

This paper is essentially a preliminary analysis of the major reactions brought on a locomotive frame, as well as of the nature of frame action as regards variation of bending moment, shear, etc., for differently supported types of frames.

A careful analysis has therefore been made of the various methods of equalization, spring design, and the nature of cab supports in electric locomotives. This is followed by a section dealing with the dynamics of the steam locomotive, where the variation of torque and a quantitative investigation of the various oscillations are discussed in detail. Further, a careful analysis of the variation of side-rod loads and journal-bearing loads is included. The succeeding section deals with electric-locomotive drives and the major reactions brought on the frame. This section includes the dynamics of the electric side-rod drive, which discussion augments the previous one on side-rod loads in steam locomotives. The next section discusses the dynamics of braking, its change in load on the equalization and the reactions brought on the frame. In this section is included a brief discussion of bumping loads and dynamical loads on the drawbar.

For a more quantitative investigation of the effects of vertical loads the bar frame has been approximately treated as a continuous beam under equalizer-applied loads and boiler supports, and the variations of bending, shear, etc., for the U. S. Standard Pacific locomotive are computed in detail in Appendix No. 1. Following this is a careful analysis of the stresses resulting from longitudinal loads due to traction, etc.

Finally, the nature of the lateral reactions and the dynamics of lateral oscillations on entering a curve, etc., are discussed, a short recapitulation of the static reactions while on a curve being also given.

A brief outline of methods of analysis coördinating with future experimental work is discussed in Appendix No. 2.

U. S. Navy Crane Ship No. 1

(*Continued from page 341*)

ends of a cross-shaft supported in bearings in the housings. This shaft is driven by two 110-hp. General Electric type M.B. No. 107 motors to which it is geared by two reductions of spur gearing and one herringbone reduction. The motor shaft is between the motors and is driven by separate pinions meshing with a single gear. A flexible coupling connects the pinions to the motor, and each pinion is provided with a magnetic disk brake.

The upper screws thread through nuts attached to the crane jibs while the lower nuts are carried in the back stays. All nuts are trunnion mounted, and the lower nuts are so arranged that their trunnion bearings are rigidly locked in position when the jib is raised off the cradle; but as the jib is lowered to its seagoing position, these bearings unlock automatically and the nuts slide off so that no possible tension or compression can be set up in the screws due to weaving of the ship. All of the movements of this mechanism are supplied with limit switches which prevent overtravel. A lever-operated band brake controlled from the operator's cab is attached.

The foregoing account is based on information kindly supplied to MECHANICAL ENGINEERING by the office of Rear-Adm. J. W. Beuret, Bureau of Construction and Repairs, Navy Department, Washington, D. C., officers of the League Island Navy Yard, Philadelphia, Pa., and by the Wellman-Seaver-Morgan Company Cleveland, Ohio, builders of the crane.

Discussion on Orifice Coefficients

(*Continued from page 348*)

the plane of the orifice the true pressure could be obtained at any geometrical point of the given pipe. Similarly, by extending the various curves on Fig. 5 the coefficient for any geometrical point close to or at the plane of the orifice could be obtained. He could see no reason why the most reliable position for pressure taps was in the plane of the orifice.

Mr. Hodgson had referred to the theory of dynamical similarity as applied to orifices in various sizes of pipes. Mr. Pigott had also referred to it, stating that Dr. Buckingham had predicted the characteristics of the orifices and the behavior of the jet at the various geometrical distances as found by the test. Obviously more tests would have to be run on various sizes of pipes before the validity of the geometrical similarity would be established.